sensitive

SENSITIVE RESEARCH

35th Anniversary

DAYTON OHIO
MAR 1 4 1962 PM

An early Sensitive Research Wattmeter being tested by the Company's founders David Wolf and Vincent Cronin.

IN **1927**—3 BASIC DESIGNS.

IN **1962**—OVER 4000 CATALOG ITEMS . . . INCLUDING ***10* NEW INSTRUMENTS**

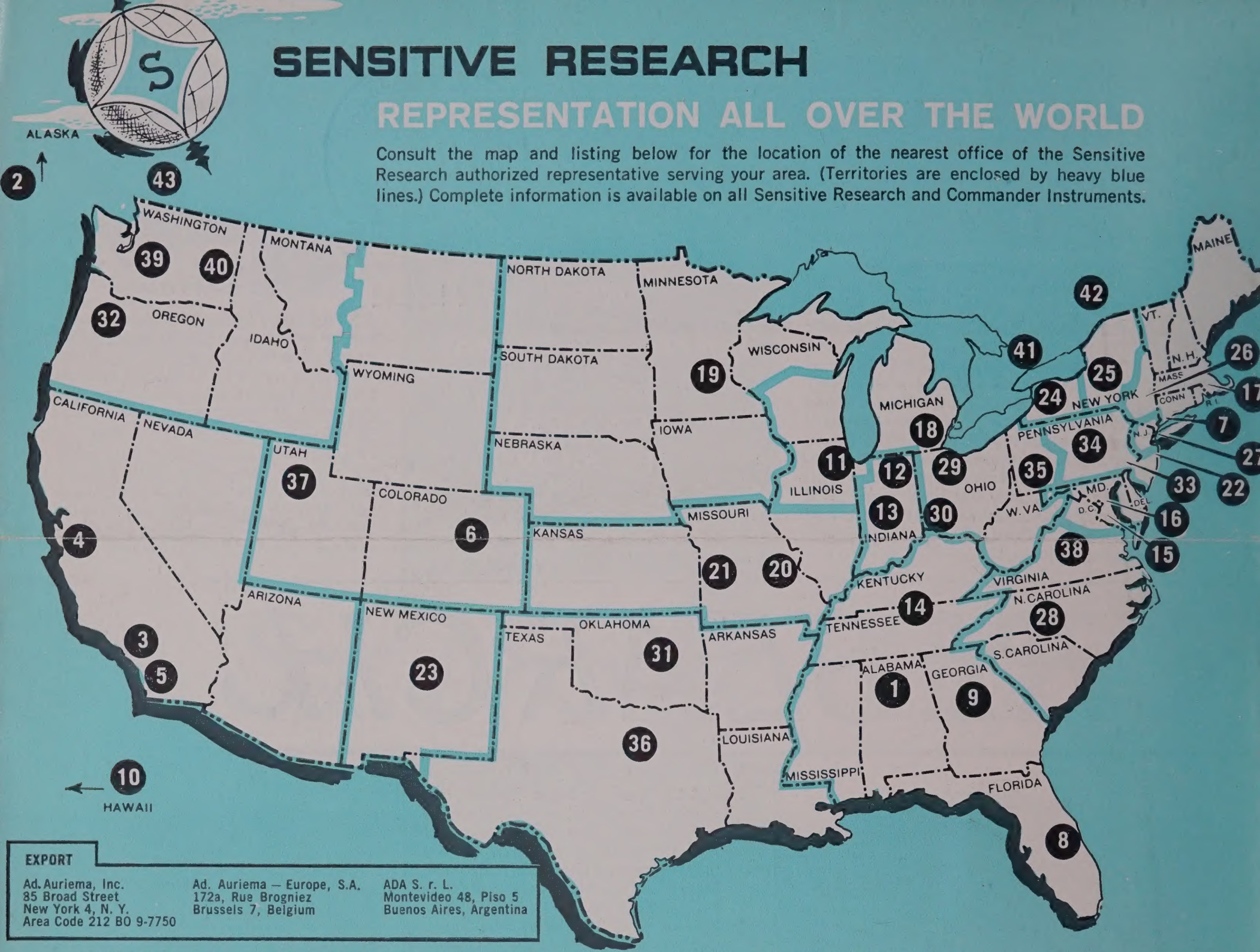
VISIT BOOTHS 3411-3413
NEW YORK IRE SHOW

COLISEUM • MARCH 26-29

SENSITIVE RESEARCH

REPRESENTATION ALL OVER THE WORLD

Consult the map and listing below for the location of the nearest office of the Sensitive Research authorized representative serving your area. (Territories are enclosed by heavy blue lines.) Complete information is available on all Sensitive Research and Commander Instruments.


ALASKA
2
43
WASHINGTON
39
40
MONTANA
OREGON
32
IDAHO
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
WYOMING
WISCONSIN
19
MAINE
42
41
VT.
N.H.
MASS
CONN
R.I.
26
17
25
24
NEW YORK
MICHIGAN
18
CALIFORNIA
NEVADA
UTAH
37
NEBRASKA
IOWA
PENNSYLVANIA
34
N.J.
7
27
11
12
29
35
33
22
ILLINOIS
OHIO
COLORADO
6
4
KANSAS
MISSOURI
13
INDIANA
30
W.VA.
MD.
D.C.
DEL.
16
15
38
21
20
KENTUCKY
VIRGINIA
N.CAROLINA
28
14
TENNESSEE
ARIZONA
NEW MEXICO
OKLAHOMA
TEXAS
ARKANSAS
31
S.CAROLINA
ALABAMA
GEORGIA
1
9
3
5
23
36
LOUISIANA
MISSISSIPPI
FLORIDA
10
HAWAII
8

EXPORT

Ad. Auriema, Inc.
85 Broad Street
New York 4, N. Y.
Area Code 212 BO 9-7750

Ad. Auriema — Europe, S.A.
172a, Rue Brogniez
Brussels 7, Belgium

ADA S. r. L.
Montevideo 48, Piso 5
Buenos Aires, Argentina

1 **ALABAMA—Huntsville**
Bivins & Caldwell, Inc.
Area Code 205 534-5733

2 **ALASKA—Anchorage**
ARVA, Inc.
P. O. Box 171
BR 2-6731

3 **CALIFORNIA—So. Pasadena**
McCarthy Associates, Inc.
511 Mission Street
Area Code 213 MU 2-3981

4 **CALIFORNIA—San Francisco**
McCarthy Associates, Inc.
1011 E. Industrial Way
Burlingame, Calif.
Area Code 415 342-8901

5 **CALIFORNIA—San Diego**
McCarthy Associates, Inc.
3460 Ingraham Street
Area Code 714 BR 4-1100

6 **COLORADO—Denver**
Lahana & Company
1886 S. Broadway
Area Code 303 PE 3-3791

7 **CONNECTICUT—Bridgeport**
Yewell Associates, Inc.
1101 E. Main Street
Area Code 203 FO 6-3456

8 **FLORIDA—Orlando**
Bivins & Caldwell, Inc.
P. O. Box 6941
CH 1-1091

9 **GEORGIA—Atlanta**
Bivins & Caldwell, Inc.
3110 Maple Drive, NE
Area Code 404 233-1141

10 **HAWAII—Honolulu**
ARVA, Inc.
P. O. Box 2845
269-781

11 **ILLINOIS—Chicago**
Saffro & Associates, Inc.
5209 N. Kimball Avenue
Area Code 312 JU 8-0905

12 **INDIANA—Angola**
Law Instrument Company
P. O. Box 95
Angola 217

13 **INDIANA—Indianapolis**
Law Instrument Company
P. O. Box 27062
Area Code 317 ST 7-0009

14 **KENTUCKY & N.E. TENN.**
Bivins & Caldwell, Inc.
P. O. Box 5187
High Point, N. C.
882-6873

15 **MARYLAND—Rockville**
Horman Associates, Inc.
941 Rollins Avenue
Area Code 301 HA 7-7560

16 **MARYLAND—Baltimore 15**
Horman Associates, Inc.
3006 W. Cold Spring Lane
Area Code 301 MO 4-4400

17 **MASSACHUSETTS—Burlington**
Yewell Associates, Inc.
Middlesex Turnpike
Area Code 617 BR 2-9000

18 **MICHIGAN—Detroit**
S. Sterling Company
15310 W. McNichols Road
Area Code.313 BR 3-2900

19 **MINNESOTA—Minneapolis**
The Heimann Company, Inc.
1711 Hawthorne Avenue
Area Code 612 FE 2-5457

20 **MISSOURI—St. Louis 17**
Harris Hanson Company
2814 S. Brentwood Blvd.
Area Code 314 MI 7-4350

21 **MISSOURI—Kansas City 32**
Harris-Hanson Company
7916 Paseo Street
Area Code 816 HI 4-9404

22 **NEW JERSEY—Asbury Park**
SONCO DIV. of I. E. Robinson Co.
1317 Railroad Ave.
Area Code 201 KE 1-3150

23 **NEW MEXICO—Albuquerque**
SEI, Inc.
4404 Lomas, N.E.
Area Code 505 255-2278

24 **NEW YORK—Buffalo 17**
The Robert F. Lamb Co.
3407 Delaware Avenue
Area Code 716 TR 6-3737

25 **NEW YORK—Syracuse**
J. F. Wulfetange, Jr.
4505 E. Genesee Street
DeWitt 14, N. Y.
Area Code 315 GI 6-3330

26 **NEW YORK—Poughkeepsie**
Yewell Associates, Inc.
806 Main Street
Area Code 914 GR 1-3456

27 **NEW YORK—Met. Area**
Sensitive Research
310 Main Street
New Rochelle, N. Y.
Area Code 914 BE 5-2300

28 **NORTH CAROLINA—Charlotte**
James L. Highsmith & Co., Inc.
3733 Monroe Road
Area Code 704 FR 7-2546

29 **OHIO—Cleveland 24**
S. Sterling Company
5827 Mayfield Road
Area Code 216 HI 2-8080

30 **OHIO—Dayton 39**
S. Sterling Company
Suite 103
3300 S. Dixie Drive
Area Code 513 AX 8-7573

31 **OKLAHOMA—Tulsa**
Arnold Barnes Company
P. O. Box 5417
Area Code 918 NA 7-1515

32 **OREGON—Portland**
ARVA, Inc.
1238 N.W. Glisan Street
Area Code 503 CA 2-7337

33 **PENNSYLVANIA—Philadelphia**
SONCO DIV. of I. E. Robinson Co.
144 Elizabeth Street
W. Conshohocken, Pa.
Area Code 215 CH 8-1600

34 **PENNSYLVANIA—Camp Hill**
SONCO DIV. of I. E. Robinson Co.
Park Place Office Bldg.
Area Code 717 RE 7-6791

35 **PENNSYLVANIA—Pittsburgh 27**
S. Sterling Company
G.B.U. Building
4232 Brownsville Road
Area Code 412 TU 4-5515

36 **TEXAS—Dallas 19**
Arnold Barnes Company
3603 Lemmon Avenue
Area Code 214 LA 6-8735

37 **UTAH—Salt Lake City**
Lahana & Company
1482 Major Street
Area Code 801 HU 6-8166

38 **VIRGINIA**
Richmond and Southern Area
James L. Highsmith & Co., Inc.
Charlotte, No. Carolina
Northern Area
Horman Associates, Inc.
Rockville, Maryland

39 **WASHINGTON—Seattle 9**
ARVA, Inc.
1320 Prospect Street
Area Code 206 MA 2-0177

40 **WASHINGTON—Spokane 10**
ARVA, Inc.
East 127 Augusta Ave.
Area Code 509 FA 5-2557

CANADA

41 **ONTARIO—Toronto**
MEL Sales, Ltd.
71 Crockford Blvd.
Scarborough, Ontario
Area Code 416 755-9235

42 **QUEBEC—Montreal**
MEL Sales, Ltd.
P. O. Box 1352
Postal Sta. "O"
Area Code 514 NA 7-4313

43 **BRITISH COLUMBIA—Vancouver 9**
ARVA, Inc.
1624 W. 3rd Avenue
Area Code 604 RE 6-6377

SENSITIVE RESEARCH INSTRUMENT CORPORATION

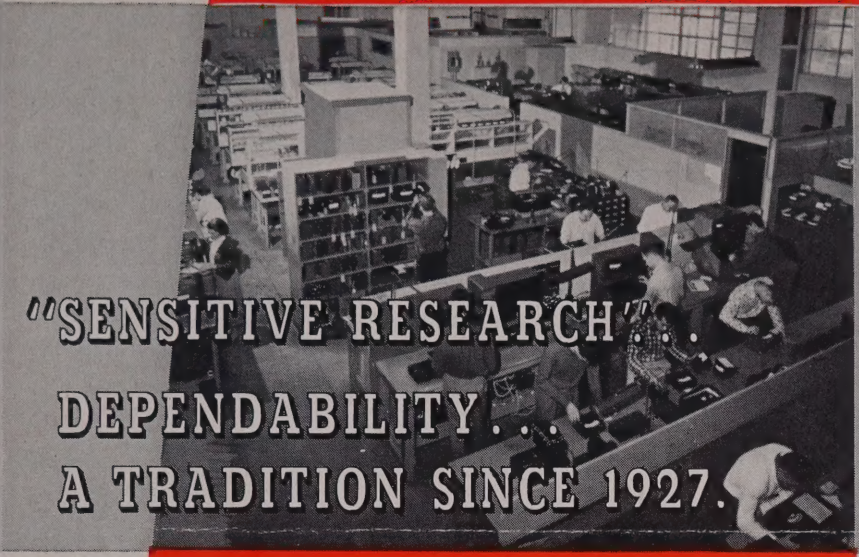
COMMANDER INSTRUMENTS

NEW ROCHELLE, N.Y.

Telephone: Area Code 914 BE 5-2300

PRINTED IN U.S.A.

DEC 18 1959 PM
DAYTON, OHIO



"SENSITIVE RESEARCH"... DEPENDABILITY... A TRADITION SINCE 1927.

Your inspection of our modern facilities is welcomed. We'd be delighted to show you how a fine instrument is made.

SHORT FORM CATALOG...

OF ELECTRICAL INDICATING INSTRUMENTS,

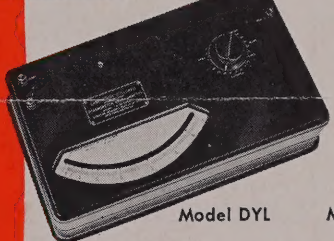
AC and DC Standardization Consoles, and related test equipment for the accurate measurement and certification of current, voltage, power, frequency and magnetic quantities.

Our periodic publication *ELECTRICAL MEASUREMENTS* is available upon request. Write for our complete current catalog.

***Model LTC*—AC-DC/DC calibration console. *Accuracy—.05% of actual reading.* Ranges—.5 v. to 1111.5 v.; 1 ma. (2 ma. on AC) to 11.115 amps. Resolution — .01%. Frequency — DC to 25 kc. Other consoles are:

Model	*% Accuracy*	*Ranges*
LTD	.05 of reading	.1 v. to 1111.1 v.; 1 ma. to 11.111 amps. DC
LTCA	.05 of reading	.5 v. to 1111.5 v.; 2 ma. to 11.115 amps. AC-DC
LTA	.05 of full scale	.3 v. to 1500 v.; 2 ma. to 30 amps. AC-DC.
LTHD	.05 of reading	0-1.6 amps.; 0-1.6 v. DC.

LABORATORY STANDARDS



Model DYL

Model THACH

Model LW — AC/DC Single Phase Wattmeter. Accuracy—.1% f.s. Multirange combinations available from 25 w. through 6 kw. f.s. at 75/150/300 v. f.s. and 80% minimum p.f. Frequency compensation to 1000 c.p.s. on special order. 12" vernier scale.

Model RFVC — Radio frequency *Self Checking* RMS voltmeter for the certification of VTVM's from DC to 10 Mc. Accuracy—.3% of full scale ±.2% frequency influence. Ranges—.01/.1/1/3 v. Checks its own accuracy against a .05% stable internal standard source.

Model DYL — AC. Accuracy—.1% f.s. 60 or 400 c.p.s. Ranges 10/20/50/100/200/500 ma.; 1/2/5/10 amps.; 20/50/100/200/500 v. f.s. 12" venier scale. **Model THACH** — AC/DC *Self Checking* Volt-Amp-Milliammeter. Accuracy — .2% f.s. to 4 kc. Ranges — 10/20/50/100/200/500 ma.; 1/2/5 amps.; 1/2/5/10/20/50/100/200/500/1000v. f.s. Checks its own accuracy against an internal standard cell. Special regulated **THACH Power Supply** (optional) automatically shuts off power to the THACH when switching ranges, reducing possibility of accidental overloads. Output is DC or 60 c.p.s. (400 c.p.s. can be plugged in).

Model BS — *Self Checking* DC Volt-Amp-Milliammeter. Accuracy .05% f.s. 25 ranges. .3 v. to 1.5 kv.; 1.5 ma. to 15 amps. f.s. Checks its own accuracy against an internal standard cell. **Model B** — DC. Accuracy .1% f.s. Multirange I or E combinations from 30 μa. and 50 mv. to 1000 amps. and 10 kv. f.s. **Model L** — AC/DC. Accuracy .1% f.s. Multirange I or E combinations from 50 ma. and 30 v. to 20 amps. and 1 kv. Frequency compensation to 1000 c.p.s.
Models BS, B and L have 12", hand-drawn vernier mirrored scales. Diamond Pivots and shock-mounted jewels.

SENSITIVE RESEARCH INSTRUMENT CORPORATION

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

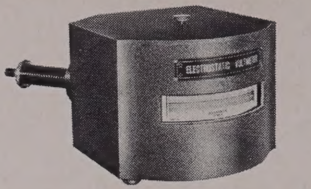
NEW ROCHELLE, N. Y.

S
Symbol of Quality

Permanently Precise!

AC-DC ELECTROSTATIC VOLTMETERS

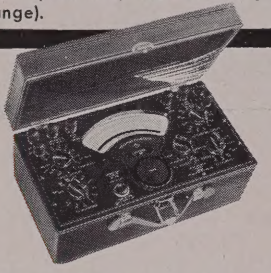
Model CRV — Crest or peak voltmeter for reading true RMS, negative peaks and positive peaks. Accuracy—1% f.s. for basic 0-1 kv. instrument. 1% multipliers available up to 100 kv. for AC or pulsed DC measurements. 5.2" scale. For pulses of 20/sec. or more. High input impedance (varies according to range).



Model ESH - Accuracy-1% f.s. (.5% on special order). Single or multirange combs. from 5 kv. to 100 kv. f.s. 6" scale. Input impedance up to 5 x 10^{15} ohms. Reads true RMS. Switch controlled from rear. Transit lock and brackets for panel mounting available. Adaptor for peak voltage reading. All electrostatics have a modified square law scale.

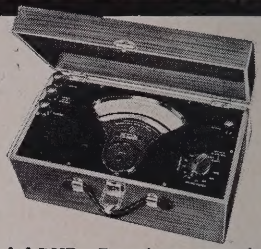
Model ESD — Accuracy — 1% f.s. (.5% on special order). Single or multirange from 120 v. to 6 kv. f.s. 5.2" scale. Reads true RMS. Input impedance 10^{15} ohms. **University Model**—Accuracy—1%; ranges from 300 v. to 5 kv. f.s. 4" scale. **Model VPA**—Peak voltage adaptor up to 30 kv. maximum inverse peak rating.

AC-DC POLYRANGERS



Model U88 — Accuracy — .5% DC; .75% AC/DC f.s. (thermocouple side). 88 ranges f.s. from 200 µa. to 1.5 amps.; 20 mv. to 750 v. DC, and 10 ma. to 3 amps.; .5 v. to 750 v. AC/DC. Frequency 5 kc. on E and 15 kc. on I. 5.2" scale. Automatic Temperature Compensation. **Model USP**—similar to above but 28 ranges.

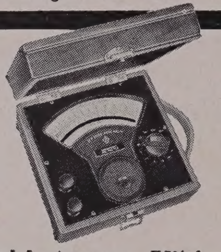
Model C — Rugged DC, .25% f.s. accurate reference standard. 14 ranges f.s. from 1.5 ma. to 3 amps.; 1 v. to 1 kv. (2 combs.) 1 sec. period. 6.3" scale. **Model WVA** — same, but 27 f.s. ranges from 1 ma. to 15 amps.; 100 mv. to 1 kv. **Model S**—Accuracy-.5%. Sensitivity to 10,000 ohms/v.; 5 mv.; 100 µa. 13 ranges. 5.2" scale.



Model DYP — Transformer coupled dynamometer for 60 c.p.s. AC testing. Accuracy — .3% f.s. 20 f.s. ranges from 5 ma. to 10 amps.; 5 v. to 2 kv. 6.3" scale. **Polyrangers** are portable, general purpose I and E measuring instruments. Other models and range combinations available. Write for a complete listing.

AC-DC THERMOCOUPLE INSTRUMENTS

Model XT—R.F. ammeter. Accuracy —1% f.s. DC to 70 Mc. Single range from 1 amp. to 100 amps. (higher on special order). Automatic Temperature Compensation. 6.3" scale. **Model RF**—same, but ranges 1 ma. to 1 amp. f.s. Frequency — 1 Mc. (4 range unit 250 kc.). **Model AU** — Accuracy-.5% (on special order) up to 20 kc.

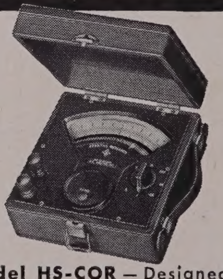


Model A—Accuracy—.75% f.s. (.5% on special order). Single or multirange switch controlled f.s. ranges from 1 ma. to 1.5 amps.; .2 v. to 1.5 kv. Frequency — up to 7 kc. on E; 15 kc. on I. Automatic Temperature Compensation. 6.3" scale. Thermocouple instruments are available with a thermocouple replacement feature and overload protective shunt.

Model RFV—Radio frequency voltmeter. Accuracy — .5% f.s. ± .5% max. frequency influence on switch controlled multirange units from 1 v. (5 Mc.) to 300v. f.s. (150 kc.). Single range instruments of 1v. or 3 v. f.s. have an upper frequency limit of 10 Mc. Automatic Temperature Compensation. 6.3" scale. Can be certified on DC. Frequency influence constant.

DC CORROSION AND ELECTROLYSIS INSTRUMENTS

Model PV — Potentiometer voltmeter — measures *true potentials* with zero current drain. Accuracy — .5% f.s. Multirange combs. from 2 mv. to 20 v. f.s. 5.2" scale. **Model ZR**—Zero resistance micro-milliammeter having a zero *volt* loss. Accuracy—.5% f.s. Multirange combs. from 10 µa. to 300 ma.



Model HS-COR — Designed for rugged field use for A. T. & T. and Bell Tel. Labs. Accuracy — .5% f.s. Multirange combs. from 5 mv. to 100 v. Sensitivities to 1 megohm/v. 6.3" scale. Features the *formica case, Diamond Pivots, and special non-slip binding posts for alligator clips.*

Diamond Pivots and shock mounted jewels are included in all Laboratory Standards and ultra high sensitivity instruments (thermocouple meters, low resistance microammeters, etc.) They are many times more shock resistant than conventional pivots and jewels, and their installation assures a friction free moving element under the severest operating conditions.

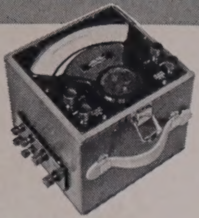
Symbol of Quality

SENSITIVE RESEARCH

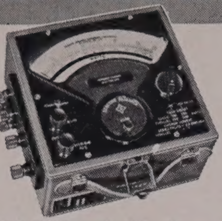
310 MAIN STREET • NEW ROCHELLE, N. Y.

ELECTRICAL INDICATING INSTRUMENTS

AC-DC WATTMETERS



Model PDLW — Polyphase wattmeter for use down to 20% p.f. Accuracy—.75% f.s. up to 500 c.p.s. Multirange combs. from 1.5 w. to 2.4 kw. f.s. at 75/150/300 v. f.s. (frequency limits of 2.5 kc. on special order) 5.2" scale. **Model PDW** — same, but accuracy — .25% f.s. down to 50% p.f. and up to 800 c.p.s. Ranges from 15 w. f.s. at 50/100/200 v. f.s. 6.3" scale.



Model DW — Single phase reference standard wattmeter. Accuracy — .25% f.s. to 50% p.f. and up to 800 c.p.s. Multirange combs. from 5 w. to 2 kw. f.s. at 50/100/200 v. f.s. 6.3" scale. **Model DLW**—same, but accuracy .5% f.s. down to 20% p.f. and up to 500 c.p.s. Ranges from .2 w. f.s. at 75/150/300 v. **University Model** — same, but 4" scale and reduced accuracy.

Model VAW—Volt-Amp-Wattmeter. AC. Accuracy—.5% f.s. for E. and I.; .75% f.s. for w. Ranges for "50-800 c.p.s." model—50/100/200/250/500 w.; 1/2/2.5/5 kw. f.s. at 100/200/500 v. f.s. down to 50% p.f.; "50-125 c.p.s." model has additional ranges of 12.5/25 w. f.s. and 25/50 v. f.s.

AC-DC VOLTMETERS AND AMMETERS

A NEW portable Field instrument

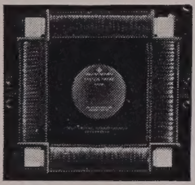
Model N — Economically priced, rugged DC and AC voltmeters and ammeters. Accuracy — .5% f.s. Switch controlled. Range combs. — 50 mv. to 1.5 kv. (up to 5 k.-ohms/v.); 50 μa. to 50 amps. DC; 5 v. to 750 v.; 10 ma. to 10 amps. AC. *Long 6" scale.* Moulded bakelite case with carrying strap. *Can be supplied for panel mounting.*

Portable double pivoted D'Arsonval,[1] dynamometer,[2] and moving iron[3] instruments. Single and multirange. Switch controlled to 5 amps. and 1 kv. Self-contained to approximately 20 amps. and 1.5 kv. (DCHI to 30 kv.)

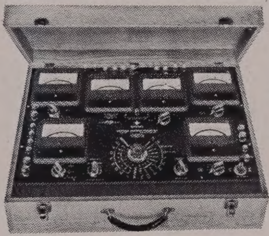
UNIVERSITY MODEL

Model	*Accuracy*	*Scale*	*F.S. Ranges Start At*
[1]**C**	.25% f.s.	6.3"	DC 30 μa; 50 mv.
[1]**S**	.5% f.s.	6.3"	DC 1 μa; 1 mv.
[1]**UNIV.**	.5% f.s.	4"	DC 2 μa; 1 mv.
[1]**DCHI**	1% f.s.	4"	DC 1.5 kv. 50k Ω/v.
[2]**D**	.25% f.s.	6.3"	AC/DC 5 ma; 1.5 v.
[2]**UNIV.**	.5% f.s.	4"	AC/DC 10 ma; 7.5 v.
[3]**MI**	.5% f.s.	6.3"	AC 10 ma; 7.5 v.

MAGNETIC TESTING INSTRUMENTS

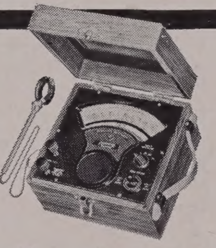


EPSTEIN FRAME



Model MAT

Test set, designed in accordance with ASTM specifications (sec. A341-49 and A343-49), for core loss measurements, determination of hysteresis loops and magnetization curves, magnetic field and AC permeability tests. Inductors above and below 1 amp. available. Includes automatic internal power compensation circuit. Contains a DC ammeter, AC ammeter, RMS voltmeter, flux voltmeter, low p.f. wattmeter, and fluxmeter with convenient overlapping ranges. **Model COL** — core loss test set with special .25% f.s. accurate flux voltmeter (6.3" scale), RMS voltmeter, ammeter and wattmeter.

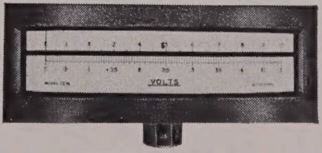


Model FM — a zero torque multirange fluxmeter calibrated in maxwells. Reads changes in flux linkage of a search coil as it moves in a magnetic field. Accuracy-.5% f.s. Sensitivity 1000 lines/div. using standard 10 turn search coil (1000 turn coil = 10 lines/div.). 5.2" scale. **Calibrated search coil and magnet** available for certification purposes.

AC-DC PANEL INSTRUMENTS

SRIC instruments have hand-drawn mirrored scales, electrostatic and magnetic shielding and temperature compensation. Portables in general conform to ASA specs C39.1-1951 for either .25% or .5% class instruments. *All SRIC products are calibrated against primary standards that have National Bureau of Standards Certificates of Accuracy and are unconditionally guaranteed for materials and workmanship for a period of one year.*

Model JWSP

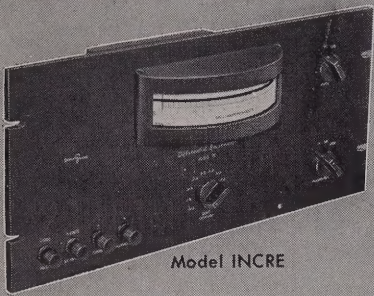


TYPE EW CASE

All of the models described in this brochure, and in our complete catalog, are available as edgewise panel instruments with *no loss in accuracy or sensitivity*. Scale lengths — 5" (type EW-5) and 7" (type EW-7). Switch controlled. Single or multirange. In some cases, such as polyrangers, they are supplied mounted in standard 19" rack panels. **Model JW** — Accuracy — .5% f.s. Max. of 3 DC ranges (B.P.'s only) from 2 μa, and 1.5 mv. f.s. Scale 4". **New Model JWSP** — same, but can contain up to 10 switch controlled ranges. **Rectangular DC and AC models** available at accuracies from .5% to 1% f.s.

INSTRUMENT CORPORATION

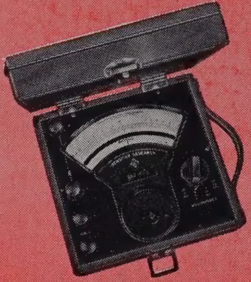
SPECIAL INSTRUMENTS
by SENSITIVE RESEARCH



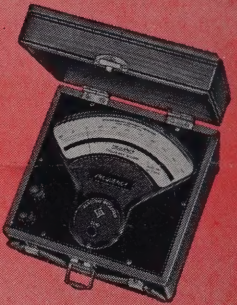
Model INCRE

Standard Volt

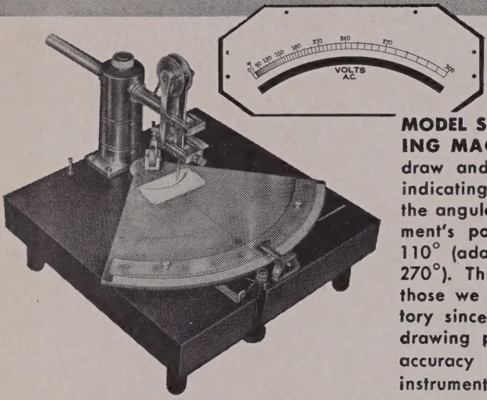
Model INCRE — Differential Incremeter. ***A NEW .05% f.s. accurate expanded scale DC standard*** for rack panel mounting or portable use. Combines the high comparison accuracy of the differential instrument with a .005% stable source. Scale has an effective length of 63" or 70", and a resolution of 1000 divisions. Each 10% of any range is expanded over the instrument's *actual* 6.3" or 7" scale length. Direct reading! No balancing or nulling! Single or multirange combinations from 200 μa. to 10 amps. and 200 m.v. to 1 kv. **The Standard Volt** is the internal source used, and is available separately. Input 115 v. 60c.p.s. 25 va. Output 1.0 v. and 1.0185 v. to within .01%. (Exact E. can be certified to .001%).



Model RA measures the ratio of 2 DC currents or voltages. Accuracy — .25% max. Minimum current per coil 50 μa. Scale reads 0 to ∞. Special scales as required.

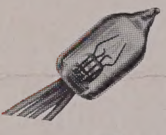


Model FRE — Frequency meter. Accuracy — .25% of center frequency (expanded scale), or of f.s. value (zero left). Ranges e.g.; 54 — 66 c.p.s.; 350-450 c.p.s.; or 0-100 c.p.s. f.s. Nominal input 115 v. and/or 230 v. ± 15%. 6.3" scale.

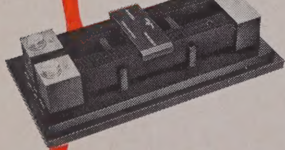


MODEL SCAMA — SCALE DRAWING MACHINE used to manually draw and print any flat electrical indicating instrument scale where the angular deflection of the instrument's pointer is no greater than 110° (adapter available for arcs of 270°). This unit is a duplicate of those we have used in our laboratory since 1927 and is capable of drawing precision scales to all the accuracy that the resolution of an instrument will permit.

INSTRUMENT ACCESSORIES

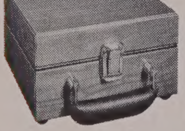


VACUUM THERMOCOUPLES (Instrument type)—Sensitivities from 1 ma. to 1 amp. Output approximately 8-10 mv. open circuit. UHF types. Isolated or contact heaters. Special long-time constants. AIR COUPLES to 100 amps. (higher on special order).



LABORATORY STANDARD SHUNTS—Accuracy—.1% or .05%. Potential drop 50 mv., 100 mv., or 300 mv. Values from 1 amp. to 1000 amps. Rated for continuous duty.

MULTIPLIERS—Available to extend voltage ranges of all instruments. Accuracy — .1% or .05%.



FORMICA CASES are available for all portable instruments normally supplied in a wood case. They are structurally strong, a good dust and humidity barrier, and will look like new for the life of the instrument.

MODEL STC — Miniature Standard Cell. Accuracy — .025%. Nominal output 1.0185 v.

Specifications subject to change without notice.

Printed in U. S. A.

FIELD ENGINEERS ALL OVER THE WORLD

AREA REPRESENTATIVES* and *OFFICES

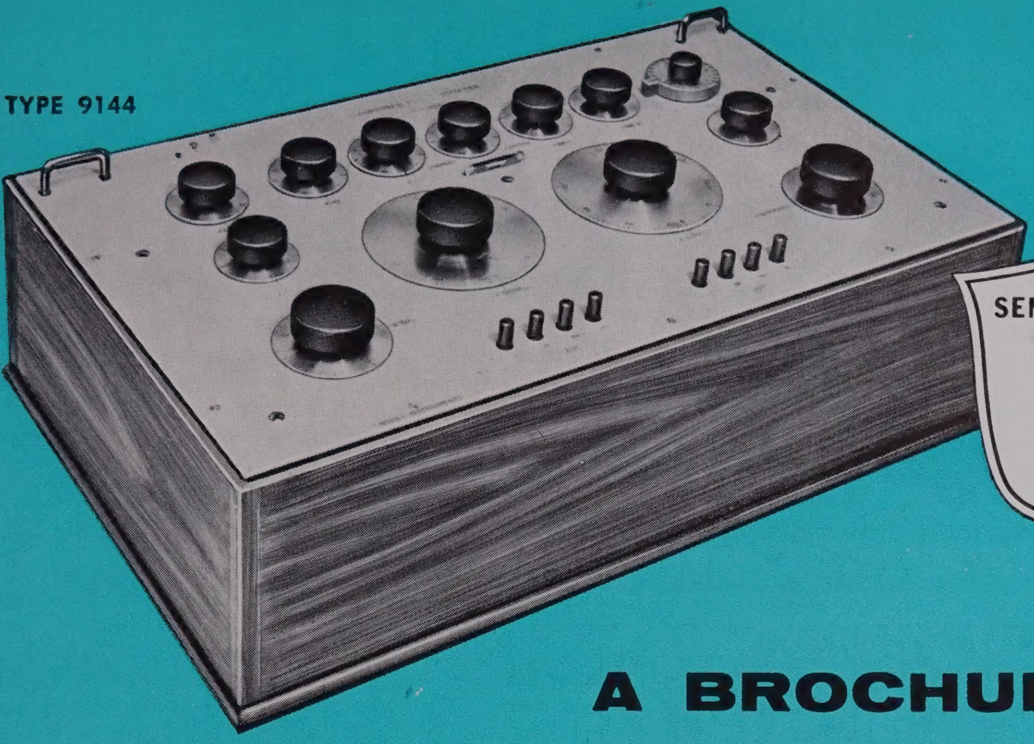
Met. New York, No. New Jersey
  Sensitive Research Home Office — New Rochelle, N. Y.
Export (Except Canada)
  Ad. Auriema, Inc. — New York City
Wash., Ore., Idaho, W. Montana, Alaska, Hawaii, W. Canada
  Arva, Inc. — Seattle, Portland, Vancouver
Georgia, Alabama, Tennessee, Kentucky, Florida
  Bivins & Caldwell — Atlanta, High Point, Orlando
New Mexico
  Gene French Co. — Albuquerque
So. Illinois, Missouri, Kansas
  Harris-Hanson Co. — St. Louis and Kansas City, Missouri
Minnesota, Iowa, Nebraska, No. & So. Dakota, No. Wisconsin
  The Heimann Company — Minneapolis
No. & So. Carolina, So. Virginia
  James L. Highsmith & Co. — Charlotte, No. Carolina
Washington, D.C. area, Maryland, Delaware
  Horman Associates, Inc. — Rockville, Baltimore
Colorado, Utah, Wyoming, E. Montana
  Lahana & Company — Denver, Salt Lake City
Western New York State
  The Robert F. Lamb Co. — Buffalo
Indiana
  Law Instrument Co. — Angola, Mishawaka, Indianapolis
Texas, Oklahoma, Louisiana, Arkansas, Mississippi
  Earl Lipscomb Assoc. — Dallas, Houston
California, Nevada, Arizona
  McCarthy Associates
  — Pasadena, Menlo Park, San Diego, Phoenix
Eastern Canada
  MEL Sales, Ltd. — Arnprior, Montreal, Toronto
E. Pennsylvania, So. New Jersey
  The I. E. Robinson Co. — Upper Darby, Camp Hill, Asbury Pk.
No. Illinois & Lake County, Indiana, So. Wisconsin
  Saffro & Associates — Chicago
Michigan, Ohio, W. Pennsylvania, West Virginia
  S. Sterling Company — Detroit, Cleveland, Dayton, Pittsburgh
Central New York State
  J. F. Wulfetange, Jr. — DeWitt
New England & Hudson River Co.'s, N. Y.
  Yewell Associates, Inc.
  — Burlington Mass.; Bridgeport, Poughkeepsie

S
Symbol of Quality

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927



TYPE 9144

A SENSITIVE RESEARCH COMMANDER INSTRUMENT

MANUFACTURED BY GUILDLINE INSTRUMENTS LTD.

RECEIVED
ENGINEERING ASSOCIATES
6 1960

A BROCHURE OF ELECTRICAL MEASURING STANDARDS

SENSITIVE RESEARCH INSTRUMENT CORPORATION

Symbol of Quality

NEW ROCHELLE, N. Y.

DAUPHINEE POTENTIOMETER TYPE 9144

The Type 9144 is a 4 dial, 6 figure DC vernier Potentiometer with an *accuracy of at least 10X that of similar commercially available equipment.* Internal quality control demands that the linearity be initially adjusted to better than 2 ppm. Stability is guaranteed to be better than 1.5 ppm per year. The instrument is remarkable in the unique precautions that have been taken in the design to reduce the importance of the contact resistance of all emf dials to a position of minor significance. In addition to being a superb measuring potentiometer it is:

1. A Resistance Comparator to an accuracy of ± 2 ppm (.0002%). Deviations of ± 50 ppm in the standard resistor used can be dialed into the potentiometer, and therefore the unknown resistor can be compared against the certificated value of the standard resistor directly without requiring corrections or computations.
2. A Saturated Standard Cell Comparator that will detect differences of ± 1 μv.
3. A precision 4 Terminal 21 Ω standard resistor (variable in steps of 10 μΩ) to an accuracy of ± .01%.
4. A Standard Cell Enclosure internally air thermostated at 28°C and containing a bank of two ± .001% accurate Type 4305 Saturated Standard Cells.

The Type 9144 Potentiometer is based on an original design by Dr. T. M. Dauphinee of Canada's National Research Council. All rights to the design are protected by a United States Patent application.

SPECIFICATIONS

ACCURACY: X1 Range ± (.001% of reading + .5 μv)
X0.1 Range ± (.001% of reading + .1 μv)

RANGES: X1 Range 2.101010 V.; X0.1 Range 0.2101010 V
The third dial has an additional negative step of 10 μv. Ranges are switch controlled.

RESOLUTION: Reads in increments of 1 μv on X1 range and 0.1 μv on X0.1 range.

STANDARD CELL CIRCUITS: Range is from 1.017500 V to 1.020100 V adjustable to ±1 μv. Separate switch positions are provided for connection to either internal standard cell or one external standard cell.

GALVANOMETER CIRCUITS: A separate galvanometer circuit is provided for the monitoring of the standard cell emf while making potentiometric measurements. Each circuit has a 4 position (Lo, M, Hi, and Reverse), low thermal emf (less than .01 μv), push button sensitivity switch with self wiping copper contacts. The potentiometer input resistance varies from 35 Ω at zero to 150 Ω at maximum setting. Recommended galvanometer is Type SR 21 in conjunction with Photocell Amplifier Type 5214.

BATTERY CIRCUIT: A 6 V battery is required. The current drain is 20 ma for all settings. 3 decade dials and 2 continuously variable shunted resistors enable the user to adjust the battery current to better than 1 ppm.

THERMAL EMFs: Residual thermal emfs less than .1 μv. Emfs generated by rotation of the switches are negligible.

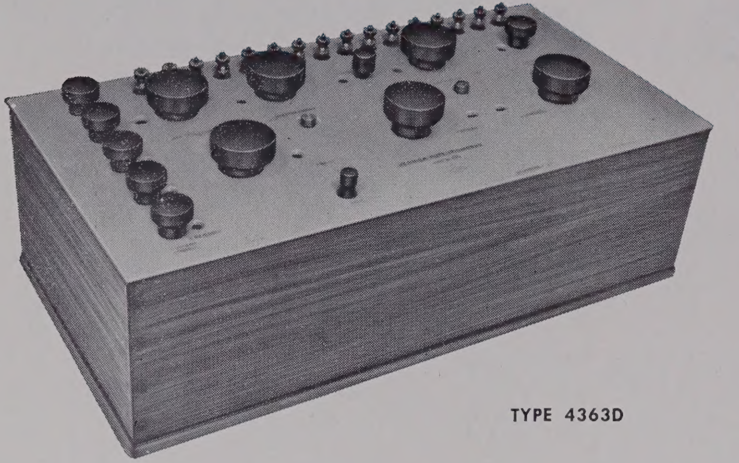
READOUT: Directly on 4 dials; 20 steps of .1 V, 100 steps of .001 V, 100 steps of .00001 V, 10 steps of .000001 V. *No slide wire with its attendant inaccuracy and maintenance problems.* Every switch step is an individually calibrated position.

CERTIFICATION: Completely "Self Checking." There is no more accurate way of certifying the potentiometer.

GENERAL: Switch contacts and all terminals are made of copper for thermal free operation. Design and construction of switches is unique, and assures long life and a minimum of maintenance. Instrument is mounted in a metal lined box and paneled externally with a walnut grained formica for maximum durability and resistance to humidity and dust. Special attention is given to guarding and shielding. Case size is 24½" x 14½" x 9" high. Weight is approx. 60 lbs.

COMMANDER INSTRUMENTS ARE MANUFACTURED FOR SENSITIVE RESEARCH BY GUILDLINE INSTRUMENTS LTD. [FORMERLY TINSLEY INSTRUMENTS (CANADA) LTD.]

POTENTIOMETERS



TYPE 4363D

DC POTENTIOMETER TYPE 4363D

The Type 4363D is a 4 dial, 6 figure DC vernier Potentiometer. Although more economical in cost than the Type 9144, it is nearly its equal in precision and accuracy. The instrument does not have a slidewire and therefore the attendant inaccuracy and stability difficulties that are associated with such a component part are non-existent. Each switch position on the main dials is an individually calibrated point.

RANGE POSITION	MEASURING RANGE	RESOLUTION	THERMAL EMFs MAX.	ACCURACY
X1	−15 µv to +1.901010 V	1 µv	0.5 µv	±(.0015% + 1 µv)
X0.1	−1.5 µv to +0.1901010 V	0.1 µv	0.5 µv	±(.0015% + 0.5 µv)

Internal quality control demands that the linearity be initially adjusted to better than 3 ppm. Stability is guaranteed to better than 1.5 ppm per year. A 5 position copper selector switch connects the potentiometer to the standard cell circuit or any one of 4 pairs of copper measuring terminals. A 2 position plug selects either the X1 or the X0.1 range. The standard cell circuit has a range of 1.01806 V to 1.01846 V in 20 steps of 20 µv. Provision can be made for other standard cell values and finer adjustment if necessary. A 4 V battery is required and the current drain is approx. 20 ma. 4 decade dials and a continuously variable shunted resistor enable the user to adjust the battery current to better than 1 ppm. Resistance of the instrument changes from approx. 1 Ω at zero to 90 Ω at maximum setting. A lock-down galvanometer press key operates in conjunction with a 4 position sensitivity switch. The galvanometer recommended for use with it is the Type 4500/SR4 with a 10 Ω coil resistance or the Type SR21 and Type 5214 Photocell Galvanometer Amplifier. Case is of formica. Size is 27″ x 12½″ x 7½″ high. Weight is approx. 56 lbs.

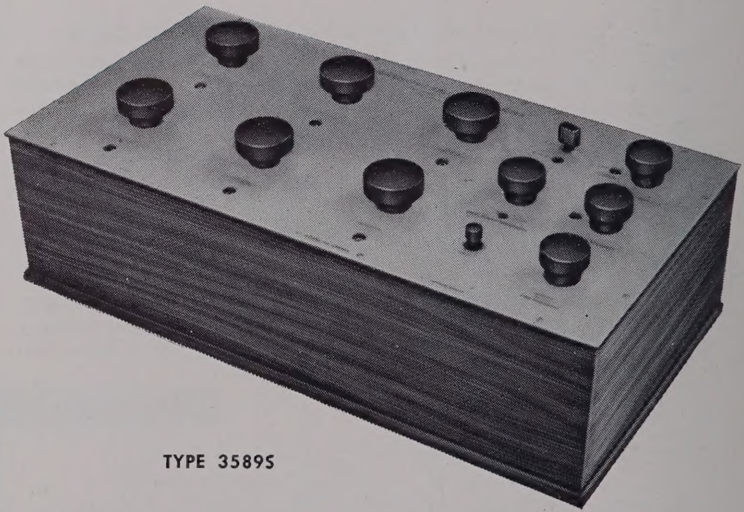
The standard cell dials of Potentiometers Types 4363D, 4363A, 3589S and 4025 are adjusted to cover a standard cell operating temperature range of 23°C to 31°C.

DIESSELHORST POTENTIOMETER TYPE 3589S

The Type 3589S is a 5 dial, 6 figure, thermo-electric free DC Potentiometer constructed to the same basic design (except for manufacturing refinements) as was first described by H. Diesselhorst in 1908. In this circuit the output is derived from the difference in potential between tapping points along two (2) parallel connected resistor chains. Because this circuit arrangement reduces to negligible proportions the effects of thermal emfs due to temperature differences and manipulation of the switches, the Diesselhorst potentiometer is particularly suitable for the measurement of small emfs. Internal quality control demands that the linearity of the Type 3589S be adjusted to better than 10 ppm. The design eliminates the use of a slidewire with its possible malfunctions. Each switch position on the main dials is an individually calibrated point.

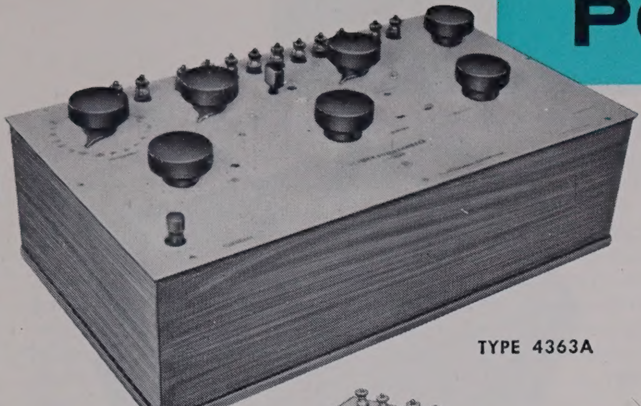
RANGE POSITIONS	MEASURING RANGE	RESOLUTION	THERMAL EMFs MAX.	ACCURACY
X1	−0.011111 V to +0.111110 V	1 µv	0.1 µv	±(.003% + 0.5 µv)
X0.1	−0.0011111 V to +0.0111110 V	0.1 µv	0.1 µv	±(.003% + 0.1 µv)

Alternative ranges can be supplied if required. (As an example — both ranges can be reduced by a factor of 10.) The potentiometer is designed for use with a 2 V lead acid cell. Battery current is controlled at a nominal 10 ma by a 21 position switch and a 10 turn rheostat with continuous resolution. The standard cell range is between 1.01806 V and 1.01846 V, and the circuit can be standardized to ± 10 µv of the standard cell voltage. A 3 position copper switch connects the standard cell to the galvanometer, or connects the potentiometer and galvanometer to either of 2 pairs of copper measuring terminals. The X1 range is changed to X0.1 by means of a plug connection. Resistance of the instrument is a constant 25 Ω for all settings. Galvanometer damping and sensitivity are constant, thereby facilitating the observation on a galvanometer of small fluctuations in a measured potential. A 3 position sensitivity switch is provided. Recommended galvanometer is the Type 4500/SR4 with a 5 Ω coil resistance or the Type SR21 and Type 5214 Photocell Galvanometer Amplifier. Case is of formica. Size is 29″ x 14″ x 10″ high. Weight is approx. 58 lbs.

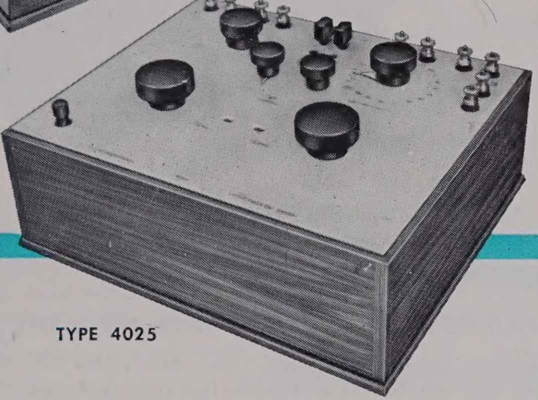


TYPE 3589S

POTENTIOMETERS



TYPE 4363A



TYPE 4025

DC POTENTIOMETER TYPE 4363A

The Type 4363A is a 3 dial, 5 figure DC vernier Potentiometer for general purpose use. It is similar in design to the Type 4363D except as otherwise noted. It is therefore ideally suited for those applications requiring more stability and accuracy than obtainable with a slide-wire type of instrument. Every switch position on the main dials is an individually calibrated point and no interpolation of reading is required. Internal quality control demands that the linearity of the potentiometer be adjusted to better than 10 ppm.

RANGE POSITION	MEASURING RANGE	RESOLUTION	THERMAL EMFs MAX.	ACCURACY
X1	−10 μv to +1.90100	10 μv	1 μv	±(.003% +2 μv)
X0.1	−1 μv to +0.190100	1 μv	1 μv	±(.003% +1 μv)

The potentiometer is for use with a 2 V battery. Current is controlled by a 20 position switch and a 20 turn rheostat with continuous resolution. A 4 position copper switch selects the standardizing circuit or any one of the 3 measuring circuits. Recommended galvanometer is Type 4500/SR4 with a 10 Ω coil resistance. Case is of formica. Size is 24½″ x 13½″ x 8″ high. Weight is approx. 35 lbs.

DC POTENTIOMETER TYPE 4025

The Type 4025 is a 2 dial, 4 figure (below 1 V) DC Potentiometer for general purpose applications where a total measuring range of 1 V is sufficient. Its convenient direct readout on two 102 position switches, and the elimination of a slide-wire in its construction are obvious advantages. It is a highly accurate, low cost, easy to operate potentiometer. Each switch position on the measuring dials is an individually calibrated point. The contacts of both dials are potential contacts only and therefore switch contact resistance has no effect on accuracy.

RANGE POSITION	MEASURING RANGE	RESOLUTION	THERMAL EMFs MAX.	ACCURACY
X1	−100 μv to +1.0200	100 μv	1 μv	±(.005% + 2 μv)
X0.1	−10 μv to +0.10200	10 μv	1 μv	±(.005% + 1.5 μv)
X0.01	−1 μv to +0.010200	1 μv	1 μv	±(.005% + 1 μv)

The standard cell circuit range is from 1.01806 V to 1.01846 V in 20 increments of 20 microvolts each. Alternative ranges of standard cell voltage can be supplied if required. The potentiometer uses a 2 V lead-acid battery. Current drain is a constant 50 ma for all settings. Potentiometer current is controlled by a 10 position switch and a 10 turn rheostat with continuous resolution. Resistance of the instrument varies from zero Ω to approximately 20 Ω at maximum setting. It has a lock-down galvanometer key and a 3 position sensitivity switch. Recommended galvanometer is the Type 4500/SR4 with a coil resistance of 10 Ω. Case is of formica. Size is 18″ x 15″ x 9″ high. Weight is approx. 28 lbs.

BRIDGES

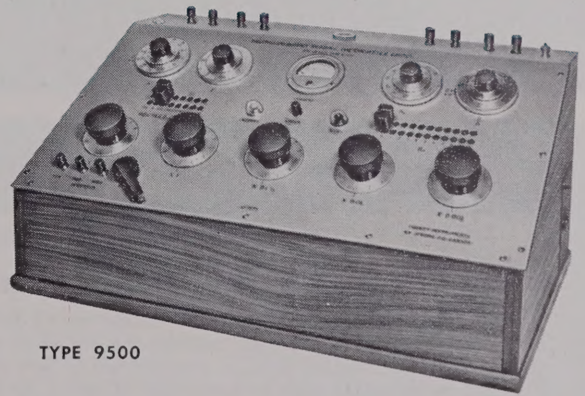
THERMOMETER BRIDGE TYPE 9500

The Type 9500 Direct Reading Resistance Thermometer Bridge was first produced in 1957 for the National Research Council in Ottawa, Canada, in accordance with a design by their Drs. T. M. Dauphinee and H. Preston Thomas. So successful was the operation of this equipment that the full details were published in the March 1960 issue of Review of Scientific Instruments. Reprints of the complete paper may be obtained on request.

The bridge has wide application, when used with a recorder, in the calibration of thermocouples, liquid in glass thermometers and some types of resistance thermometers – and when used with a thermometer and null indicator, in the determination of spot temperature. Measurements in most cases can be made into a one-man operation. It largely replaces slow and cumbersome equipment such as the Smith and Mueller Bridges or other systems such as may be set up with a potentiometer and resistor.

The Type 9500 is a six dial resistance thermometer bridge that reads directly in degrees centigrade. *It is not necessary to convert resistance readings to temperature readings.* By using any standard 25.5 Ω platinum resistance thermometer as a sensing element, the bridge subdivides the temperature scale in increments of 0.001C° from −50°C to +711.110°C with an accuracy (exclusive of that of the thermometer) of ±0.001 C°. Particular attention has been paid in the design to eliminate errors due to internal emfs and contact resistances.

The instrument includes a voltage comparator network by which the potential across the bridge resistors can be continuously compared with the potential across the thermometer element when the two are connected in series with the supply battery. The comparison is by a potentiometric method and is completely independent of current and potential lead resistances of the thermometer. The thermometer can therefore be located at a point remote from the bridge without affecting measurement accuracy. All important resistors in the measuring circuit are enclosed in an aluminum block which is thermostatically controlled at 28°C. The instrument can be checked by conventional autocalibration procedures. Power required is 110 V, 60 cps. The only external equipment necessary is a sensitive null detector. A chart recorder can be used to indicate graphically the reading of the lower two dials. This facility is made possible by the inclusion of a circuit which automatically adjusts the bridge and thermometer current so that over the full range of the temperature dials the output in volts per degree is constant and the deflectional sensitivity of the recorder is therefore also constant. The output of the bridge is .2 mv./°C. Case is of formica. Size is 22″ x 13″ x 5″ high. Weight is approx. 80 lbs.



TYPE 9500

STANDARD RESISTORS

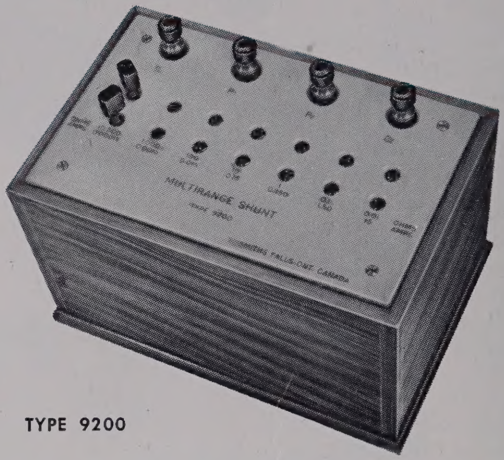
MULTIPLE STANDARD RESISTOR TYPE 9200

The Type 9200 is a ±.01% accurate Multiple Standard Resistor intended for the potentiometric measurement of direct currents from 0-15 amperes. Seven 4 terminal resistors are enclosed in a single compact unit with one set of current and potential terminals and two plugs for the selection of the required resistance value. The unit is designed for use with a potentiometer reading up to 0.15 V with a resolution of 1 μv. Stability is guaranteed to be better than 20 ppm/year. Case is of formica. Size is 11″ x 7″ x 7½″ high. Weight is 12 lbs.

Resistance values with maximum watt ratings are as follows:

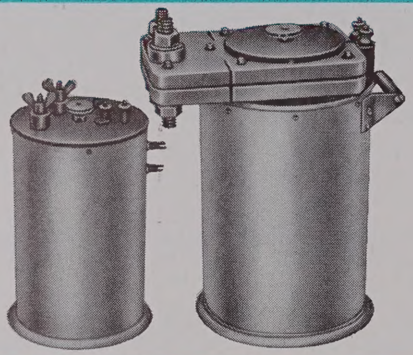
Resistance (ohms)	Watt Rating	Current Range
10,000	0.5	0 — 15μa
1,000	0.5	15μa — 150μa
100	0.5	150μa — 1.5ma
10	0.5	1.5ma — 15ma
1	0.5	15ma — 150ma
0.1	1.0	150ma — 1.5a
0.01	2.25	1.5a — 15a

Resistors are adjusted to give an accuracy of ±0.01% at any current value shown above.



TYPE 9200

Special Multiple Standard Resistors are available. Correspondence invited.



4 TERMINAL STANDARD RESISTORS TYPES 1659, 1682, 3111, and 660

The 4 Terminal Standard Resistors Types 1659, 1682, 3111, and 660 with power ratings of 10, 50, 200 and 500 watts are available for potentiometric measurements of current. All types are metal cased for oil filling. Types 3111 and 660 have water cooling tubes and a rotary impeller designed to be driven by a small motor at approx. 1000 rpm. They have time constants $\frac{L}{R}$ not exceeding $3\text{x}10^{-6}$ seconds. Types 1659 and 1682 are fitted with hand agitators. Their time constants do not exceed to 10^{-6} seconds. All these resistors are designed for use on DC and frequencies up to 1000 cps. Any resistance value between 0.0001 Ω and 10,000 Ω can be supplied on special order. Correspondence invited.

TYPE	POWER RATING IN WATTS	RESISTANCE IN OHMS	MAXIMUM CURRENT IN AMPS	% MAX. ERROR AT RATED CURRENT
1659	10	10,000	0.03	±0.03
		5,000	0.04	
		1,000	0.10	
		200	0.22	
		100	0.30	
		10	1.0	
		5	1.4	
		2	2.2	
		1	3.0	
		0.5	4.5	
		0.2	7.0	

TYPE	POWER RATING IN WATTS	RESISTANCE IN OHMS	MAXIMUM CURRENT IN AMPS	% MAX. ERROR AT RATED CURRENT
1682	50	0.2	15	±0.03
		0.1	22	
		0.05	30	
		0.02	50	
3111	200	0.02	100	±0.03
		0.01	140	±0.05
		0.005	200	±0.05
660	500	0.001	700	±0.05
		0.0005	1000	
		0.0001	2250	

SATURATED STANDARD CELLS AND

UNMOUNTED SATURATED STANDARD CELL TYPE 4305

The Type 4305 is a 0.001% accurate Unmounted Saturated Cadmium Cell for use as a working reference cell with potentiometers or as a standard for the calibration of other cells. The emf at 25°C is guaranteed to be between 1.01835 V and 1.01839 V. The cell is supplied with a certificate showing its emf over the temperature range 10°C to 40°C. (Temperature coefficient is approx. −40 PPM/C °.) The chemicals of the cell are retained by a porous partition which enables it to be shipped successfully by rail express. Testing to date indicates that it takes from 10-14 days for this cell to recover to within 2 μv (0.0002%) of its original value after such transportation. The cell is guaranteed on this basis, but if desired, arrangements can be made for personal pick-up and delivery to destination in a temperature controlled enclosure. Cells can be certified to an accuracy of ± .0001% (1 PPM).

MOUNTED SATURATED STANDARD CELL TYPES 1268 and 1149

The Type 4305 Standard Cell can be supplied mounted. The Type 1268 (Single Standard Cell) and Type 1149 (Double Standard Cell) are contained in 4″ diam. 6″ high metal cases that can be oil filled.

VOLT RATIO BOXES

*STANDARD VOLT RATIO BOX TYPES 9700 and 9700A**

The Type 9700 Standard Volt Ratio Box series is constructed to a design based on that used at the National Bureau of Standards and as described in NBS Research Paper RP 1419. *An instrument of this type is absolutely necessary for the high accuracy measurement of voltages above that of the normal range of potentiometers.* The design reduces to a minimum the two principal sources of errors in volt ratio boxes which are (1) unequal self-heating of the voltage divider chain and (2) insulation surface leakage. The instrument is self-contained in a thermostated oil bath. Oil is circulated by a motor driven impeller. Additional specifications are as follows:

RANGES: .15/.3/.45/.6/.75/1.5/3/4.5/6/7.5/15/30/45/60/75/150/300/450/600/750 V

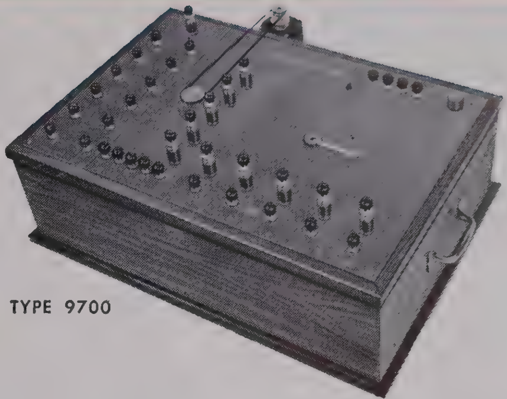
* (Type 9700A contains additional taps at 900/1050/1200/1350/1500 V constructed to the same specifications)

ACCURACY: ± .001% on initial adjustment. ± .005% or better over a 5 year period

STABILITY: ± 10 ppm or better per year

RESISTANCE: 333⅓ ohms/volt

SELF-HEATING: Total power dissipation of the working circuit is only 2.25 watts (4.5 watts in 9700A) in a temperature controlled oil bath (.25 mw/sq. cm of resistance coil at rated voltage)



TYPE 9700

SURFACE LEAKAGE: A second voltage divider chain is connected in parallel with the working potential divider and tapped at appropriate points to provide a series of guard potentials. Leakage paths are not subjected to more than 75 V and do not shunt resistance sections greater than 25,000 Ω.

Case is of formica. Size is 25″ x 17″ x 9″ high. Weight is 100 lbs. (9700A is 36″ x 19″ x 12″ high. Weight is 160 lbs.). Supplied with white mineral oil in returnable 5 gal. cans.

STANDARD VOLT RATIO BOX TYPE 4281 SERIES

The Type 4281 Volt Ratio Box Series covers ranges of up to 1500 V in various combinations. Ratio accuracy is guaranteed to be better than ± .02%. Output is 1.5 V for maximum rated input. Resistance in all cases is 100 Ω/v. Other resistance values and units with a 1 V output for rated input can be procured on special order.

TYPE	RANGES (VOLT TAPS)
4281A	15/30/75/150/300/750
4281B	15/30/75/150/300/600
4281C	150/300/600
4281D	15/30/75/150/300
4281E	15/30/150/300
4281F	150/300
4281G	30/75/150/300/600/750/900/1200/1500

TYPE 4281 G

The input terminals are also marked with multiplication factors with respect to the output terminals, which is a very useful feature. Using the Type 4281A as an example, a ratio of X2 can be obtained if the input is applied to the 30 V tap and the output is taken from the 15 V tap. This same technique can be utilized between all taps, and is an excellent way of increasing the resistance of the load applied to the measured source. The volt ratio boxes can be used for inputs of less than 15 V in conjunction with the X0.1 range of the potentiometer — without loss of resolution. As an example, when 3 V are applied to the 30 V input terminals the output is 0.15 V.

Case is of formica. Maximum size (dependent on ranges) is 15¼″ x 11¾″ x 7¹¹⁄₁₆″ high. Maximum weight is 19 lbs.

CONSTANT TEMPERATURE ENCLOSURES

CONSTANT TEMPERATURE STANDARD CELL ENCLOSURE TYPE 9152

The Type 9152 Constant Temperature Standard Cell Enclosure accommodates four Type 4305 saturated standard cells and maintains a nominal internal temperature of 28° to 36° as required with a maximum variation of ± 0.01C °. The cells are fixed to a mounting plate which slides into the inner of two aluminum cylinders. This cylinder is contained in and thermally insulated from a larger aluminum cylinder on the outside of which is wound an electrical heating element. Temperature changes are detected by a mercury-in-glass thermostat which operates a transistor switch and controls the heater current. The outer cylinder is heavily thermally lagged. In addition, a self-contained thermistor bridge serves as an internal temperature sensing element. If the bridge is connected to a 1.5 V dry cell and a galvanometer, the temperature stability can be checked to within ± .001C ° by galvanometer deflection in conjunction with a continuously variable calibrated dial that is mounted on the front panel. The dial has an 8 division scale with a value of .005°C/division.

The unit operates from a 110V/60 cps supply and is fitted with terminals for the connection of a 12 V standby lead acid battery. Change-over from 110 V to 12 V operation is automatic on failure of the AC supply.

Case is of formica. Size is 12″ x 12″ x 18″ long. Weight is approx. 30 lbs. Type 9152A accommodates up to 12 cells. Unless otherwise specified enclosures are adjusted for 28°C operation.

TYPE 9152

GALVANOMETERS

PHOTOCELL GALVANOMETER AMPLIFIER TYPE 5214

The Type 5214 Photocell Amplifier when used in conjunction with the Type SR21 Secondary Galvanometer is ideally suited for operation with DC bridges or highly accurate and sensitive potentiometers such as the Types 9144, 4363D and 3589S.

The primary galvanometer in the amplifier has a 10 ohm system and is liquid filled to reduce the effects of mechanical vibration. The galvanometer light beam differentially illuminates two barrier layer photocells which are connected in series opposition. (See Fig. 1) The photocell current resulting from an out of balance condition is used to deflect the rugged secondary galvanometer Type SR21 and at the same time to provide negative feedback. This output can also be used to feed any other resistive load of approximately 100 to 1000 ohms.

The degree of negative feedback is adjustable by means of a continuously variable potentiometer which functions as a gain control.

To avoid instability or zero drift, precautions have been taken to eliminate temperature gradients across junctions of dissimilar metals. A high insulation resistance is maintained and the copper input and output terminals are shielded from air currents by a removable cover to reduce the generation of thermal emfs.

Power to the galvanometer amplifier lamp must be supplied from an external 6 volt, 15 watt constant voltage transformer or a 6 volt lead-acid battery. Suitable transformers can be supplied for use with the amplifier. Case is of aluminum. Size is 6″ x 6½″ x 14″ long. Weight is approx. 12 lbs.

As an optional accessory a Type 5214A Thermal Compensator is available. The Thermal Compensating unit is connected in series with the input to the Photocell Amplifier. It incorporates a four position sensitivity control and a continuously variable dial which introduces ±2 microvolts into the amplifier input circuit. This can be used to counteract thermal emfs in the wiring and make the electrical and mechanical zero of the secondary galvanometer coincident.

TYPE SR21

SECONDARY GALVANOMETER TYPE SR21

The Type SR21 Secondary Galvanometer has a current sensitivity of 0.002 μa/mm, a system resistance of approximately 500 ohms and a period of approximately 2.5 sec.

It contains on its front panel an On-Off switch, a zero adjuster, and a sensitivity switch with 4 positions giving deflection multiplying factors of 1/.1/.01/.001. Scale length is 24 cms. The scale face is marked 120-0-120 mm. It is curved on a radius of approximately the same length as the secondary light beam (about 35 cms).

The overall sensitivity of the combined amplifier and secondary galvanometer system, when connected for series feedback, is normally not less than 350,000 mm/μa at maximum gain, and when connected for parallel feedback is normally not less than 13,000 mm/μa. These values can be increased 2 to 3 times by increasing the power supplied to the lamp to 36 w. Case is of formica. Size of secondary galvanometer is 13⅜″ wide x 10⅜″ front to rear x 7$\frac{3}{16}$″ high. Weight is 8 lbs. (See Fig. 2)

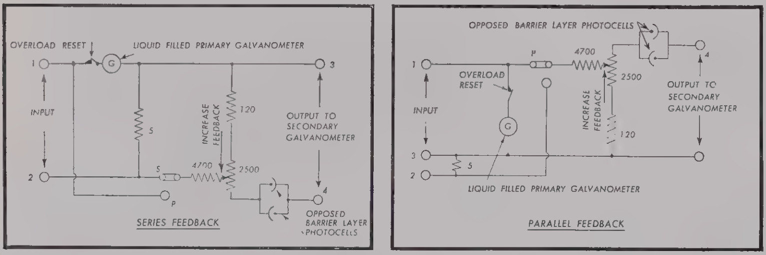
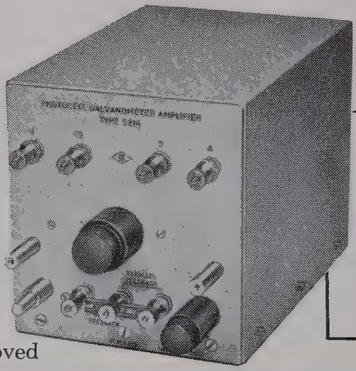
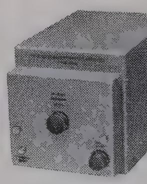

OVERLOAD RESET
LIQUID FILLED PRIMARY GALVANOMETER
G
1
2
3
4
INPUT
5
120
INCREASE FEEDBACK
4700
2500
P
OUTPUT TO SECONDARY GALVANOMETER
OPPOSED BARRIER LAYER PHOTOCELLS
SERIES FEEDBACK
OPPOSED BARRIER LAYER PHOTOCELLS
P
4700
2500
OVERLOAD RESET
INPUT
INCREASE FEEDBACK
120
OUTPUT TO SECONDARY GALVANOMETER
G
5
LIQUID FILLED PRIMARY GALVANOMETER
PARALLEL FEEDBACK

FIGURE 1.

TYPE 5214



Cover removed



With cover

TYPICAL SENSITIVITY AND INPUT RESISTANCE WITH 6V 15 WATT LAMP

Feedback	Gain	Input Resistance (ohms)	Current Sensitivity		Voltage Sensitivity with external circuit resistance of					
					Zero ohms		100 ohms		1000 ohms	
			mm/μA	μA/mm	mm/μV	μV/mm	mm/μV	μV/mm	mm/μV	μV/mm
Parallel										
Min.	Max.	0.25	13,000	0.077×10^{-9}	52×10^{3}	0.019×10^{-3}	130	7.7×10^{-3}	13	0.077
Mid.	Mid.	0.042	2,200	0.45×10^{-9}	52×10^{3}	0.019×10^{-3}	22	45×10^{-3}	2.2	0.45
Max.	Min.	0.019	1,000	1×10^{-9}	52×10^{3}	0.019×10^{-3}	10	100×10^{-3}	1	1
Series										
Min.	Max.	200	350,000	2.86×10^{-12}	1750	0.57×10^{-3}	1160	0.86×10^{-3}	290	3.45×10^{-3}
Mid.	Mid.	1700	350,000	2.86×10^{-12}	206	4.8×10^{-3}	194	5.15×10^{-3}	130	7.7×10^{-3}
Max.	Min.	2600	350,000	2.86×10^{-12}	135	7.4×10^{-3}	130	7.7×10^{-3}	98	10.2×10^{-3}

The above figures are typical but a variation of ±20% in sensitivity can be expected between different amplifiers due to variation in the characteristics of the photocells. If the lamp power is increased to 36 watts the current sensitivity on series feedback can be increased by two or three times but the sensitivity on parallel feedback is not substantially affected.

FIGURE 2.

GALVANOMETER TYPE 5180

The Type 5180 liquid filled Galvanometer is unaffected by external mechanical vibration and sudden shocks which tend to break the suspensions of standard detectors. The coil is "floated" and physically damped in a liquid which is held in a sealed container. The liquid cannot move or run out, and therefore does not transmit any movement to the coil. Resistance of the coil is either 10, 50, 140 or 450 ohms for a respective sensitivity at 1 meter of either 80, 170, 330 or 875 mm/μa. The galvanometer is normally supplied unmounted, without a scale or optical system, for inclusion in OEM or other specialized test equipment. It can be packaged to specifications on special order.

Correspondence is invited concerning the availability of special galvanometers for individualized applications.

GALVANOMETERS

GALVANOMETER TYPE 4500/SR4

TYPE
4500/SR4

The Type 4500/SR4 is a general purpose, high sensitivity Galvanometer for use with potentiometers and in other such applications as may require a vibration free, low thermal precision null-detector.

The galvanometer has an effective optical lever arm of 150 cms, although the distance between the suspension and the scale is only 33 cms. An optical magnifier with a spherical mirror permits a sensitivity of 10X that which normally could be obtained with a suspension as rugged as the one used. Because there is only one mirror reflection external to the suspension, the sensitivity is acquired without blurring the clearly defined vertical index line in the center of the main light spot – which would not be the case if multiple mirror reflections were employed. In addition to a bright primary light spot ⅝″ in diameter, the galvanometer contains a small double secondary spot with 1/10 the basic deflection sensitivity. The secondary spot is visible on the scale at all times and therefore the polarity of an over deflection can always be noted. The suspension strip passes through a drop of high viscosity, low vapour pressure oil which effectively damps the galvanometer and makes it relatively independent of bench vibrations. Thermal emfs are minimized by using copper for the external terminals and in the circuit to the suspension. Construction is generally made with high insulation resistance materials designed to provide long surface leakage paths. Scale length is 5-0-5 cms. Deflection linearity is 1% or better.

Two rotary controls are furnished on the front of the case; one is an On/Off switch and the other is a zero adjuster by which the main light spot can be moved completely over the scale. A 110/6 V transformer is self-contained to supply the galvanometer lamp. The lamp can be changed from the rear without opening the box. The galvanometer is mounted in a durable formica case with dimensions of 6½″ wide x 8¾″ front to rear x 7″ deep. Weight is 6 lbs.

The Type 4500/SR4 is available with variations in coil resistance and additional specifications as listed to the right. Periodic time is normally 2 sec. This can be adjusted to 1 sec., but sensitivity decreases by a factor of 4.

Coil Resistance	Current Sensitivity	CDRX* (ohms)	Voltage Sensitivity with total external circuit resistance of				
				Zero ohms	100 ohms	500 ohms	1000 ohms
3	45mm/μA 0.022μA/mm	20	mm/μV μV/mm	15 0.066	0.437 2.3	0.09 11	0.043 22
5	142mm/μA 0.007μA/mm	90	mm/μV μV/mm	28.4 0.035	1.35 0.74	0.28 3.5	0.14 7.15
10	210mm/μA 0.004 7μA/mm	250	mm/μV μV/mm	21 0.047	1.9 0.52	0.413 2.4	0.21 4.8
50	450mm/μA 0.002 2μA/mm	1200	mm/μV μV/mm	9 0.11	3 0.33	0.82 1.2	0.43 2.3
140	825mm/μA 0.001 2μA/mm	3500	mm/μV μV/mm	5.9 0.17	3.4 0.29	1.3 0.77	0.72 1.4
550	225 0mm/μA 0.000 45μA/mm	12,000	mm/μV μV/mm	4.1 0.24	3.46 0.29	2.14 0.46	1.45 0.69

*External critical damping resistance

CHOPPERS

LOW THERMAL CHOPPERS TYPES 9742, 9743, and 9744

The Types 9742, 9743, and 9744 are motor driven Low Thermal Choppers that have resulted from design work accomplished at the National Research Council in Ottawa, Canada. The construction of the choppers makes them particularly adaptable to circuits where thermal noise is of importance, such as in low level DC amplifier applications and Hall Effect measurements.

SPECIFICATIONS

THERMAL EMFs: 0.02μv or less.

CONSTRUCTION: Depending on Type No. contain 2, 3, or 4 DPDT switches, all actuated by a common shaft. Switch arms are made of copper. Contacts are solid gold blocks. Switch sections are separated by electrostatic screens and surrounded by heavy metal covers to maintain thermal equilibrium.

RELATIVE PHASE OF SWITCHES: Adjustable through 360° by rotating the cams on the shaft.

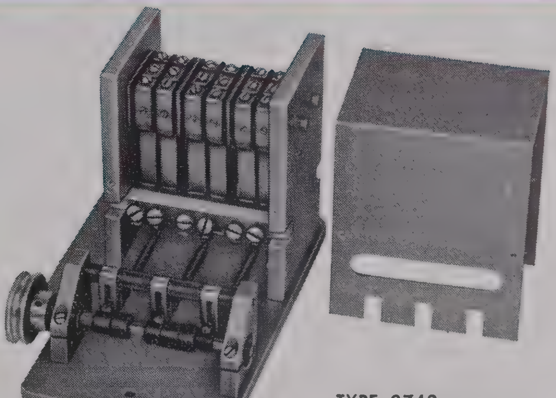
MAKE/BREAK RATIO: Each contact can be separately adjusted from 0 to 100% of a cycle with an accuracy of ± 1%.

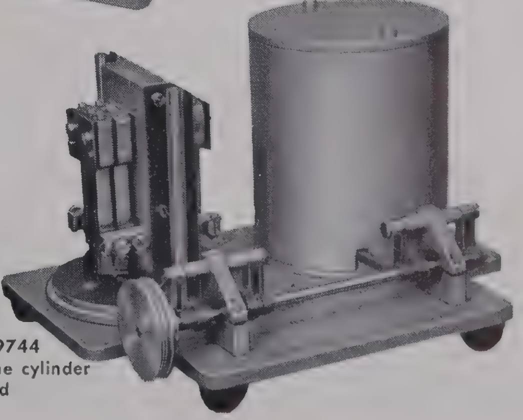
CURRENT CAPACITY: Depends whether circuit is resistive, capacitive or inductive. Will usually operate in purely resistive circuits to interrupt up to 100 millivolt amperes. Correspondence necessary for special applications.

CHOPPING FREQUENCIES: Speeds up to 60 cps. are normal. Optimum speed depends on applications, i.e. in a DC amplifier operating from a 60 cycle supply, a maximum rejection of 60 cycle pick-up can be obtained at a speed of approximately 37.5 cps. Speeds up to 90 cps. can be used by increasing the tension of the spring on the rod return.

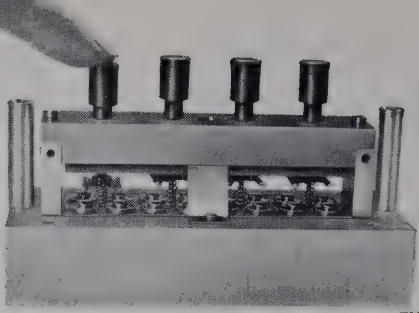
DRIVING MECHANISM: A small synchronous motor capable of a 0.8 inch-oz. torque. (Not furnished)

TYPE		DPDT SWITCHES	SIZE	WEIGHT
9742 (2 section)		2	3¾″ x 5½″ x 4½″ high	4 lbs.
9743 (3 section)	← Design miniaturized for OEM applications	3	3½″ x 5¼″ x 4″ high	2 lbs.
9744 (4 section)		4	7½″ x 5½″ x 4½″ high	9 lbs.


TYPE 9743


TYPE 9744
with one cylinder removed

SWITCHES



TYPE 9145
with panel & case removed

SELECTOR SWITCH
LOW THERMAL
TYPE 9
1
2
3
4
SMITHS FALLS ONT CANADA

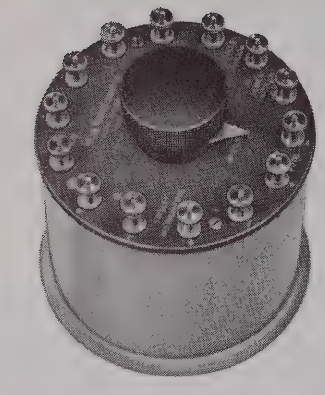
TYPE 9145

LOW THERMAL SELECTOR SWITCH TYPE 9145

The Type 9145 Low Thermal Selector Switch is intended for use in potentiometer or other circuits where stray emfs must be kept to an absolute minimum. *Maximum generation of thermal emfs is less than 0.01 μv.* The switch contains 4 DPST sections with self-wiping all tellurium-copper contacts and is mounted in a solid block of aluminum to minimize temperature gradients. Operation is made simple by allowing for the selection of any one of 4 circuits by merely depressing a push button. The buttons lock down automatically and release when any other button is depressed. Two or more buttons may be simultaneously depressed if desired. A separate release button is provided to open all circuits. The terminals can be cross connected for applications requiring a reversing switch. Size is 5⅞″ x 2⅞″ x 3⅛″ high. Weight is 2.5 lbs.

The Type 9145 is ideally suited for use as an external circuit selector with the Type 9144 Dauphinee Potentiometer.

REVERSING SWITCH TYPE 9600



TYPE 9600

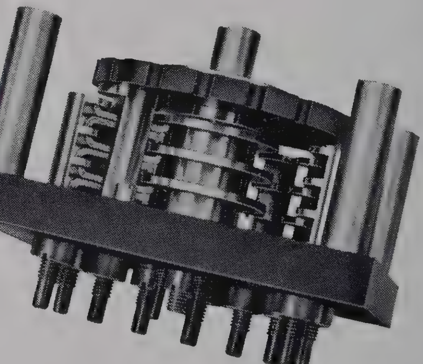
The Type 9600 is a Reversing Switch designed to simplify and speed up the operation of precision potentiometers. By a single turn of the switch the potentiometer battery and two measuring circuits are reversed and the galvanometer is disconnected during the change over. If only one measuring circuit is in use the spare section of the switch can be utilized to reverse the standard cell and thus make it possible to check the standardization of the potentiometer with either a positive or negative connection of the battery.

To eliminate errors due to thermal emfs in potentiometric measurements the balance point must be adjusted until the galvanometer deflection does not change on reversal. To perform this function effectively, the reversing switch has two outstanding characteristics: 1) In the measuring circuits and the galvanometer circuit the switch does not generate significant thermal emfs. It has copper switch contacts and low thermal solder at all junction points. The complete switch and internal wiring are immersed in oil; 2) In the battery circuit the switch contacts do not introduce a change in resistance large enough to significantly affect the potentiometer current. The design of the switch allows for an extremely high reproducibility of contact resistance. The maximum change of resistance on reversal does not exceed 100 $\mu\Omega$. In a typical potentiometer of 100 Ω resistance this would cause a change in current of 1 ppm.

The switch is enclosed in a cylindrical metal case with rubber feet. Over-all size is 5½″diam.x 6″ high. Weight is 6 lbs.

The Type 9600 is recommended for use with all "COMMANDER" potentiometers except the Dauphinee Type 9144.

DUAL CONTACT SWITCHES



Dual Contact Switch

A wide variety of standard and special Dual Contact Switches are available for AC/DC transfer and/or reversing applications demanding the highest degree of precision and reliability. The principle of the dual contact switch is illustrated in the accompanying photograph.

The complete wiper or brush is made up of two assemblies, each with 8 individually sprung contact arms that are separated and riveted together at the center. The elasticity of the wiper arms maintains the whole assembly against the inner surfaces of the center segments of the brush and the stationary contacts. This arrangement effectively allows the wiper to "float" between the stationary contacts since it is not mechanically held in place other than by the pressure of its own individually sprung arms. Hence, contact pressure — and therefore, contact resistance is always constant. Contact surfaces are self-cleaning and the design of the wiper assembly is patented with all rights reserved.

The switch contacts can be constructed of either brass or copper. Copper is used when low resistance or thermoelectric free switches are required. The generation of thermal emfs can be kept as low as .01 μv. For exceptionally low resistance applications, the wiper assemblies can be paralleled. Switches with copper contacts have a resistance as low as 100 $\mu\Omega$. between soldering points and will vary less than 10 microhms between contact points. Conversely when brass contacts are employed thermal emfs are usually about .3 μv when the switch is stationary and will vary between 2 to 3 μv when it is being rotated vigorously. Contact resistance can be as low as 2 milliohms with a variation of ±500 microhms between contact points.

Standard switches with either 5/16″ or ½″ diameter contacts are available in varying combinations of 1 — 4 poles and 2 — 25 positions. (A maximum of 4 positions for a 4 pole single deck switch.) As many as 6 decks can be supplied actuated by a single shaft. Correspondence is invited on both standard and special switches.

JUN - 1 1959 PM

Permanently Precise!

ELECTRICAL MEASURING INSTRUMENTS

CONDENSED EDITION • JUNE, 1957

In these pages are listed a condensed edition of the HIGHEST PRECISION and MOST SENSITIVE electrical measuring instruments in the world. Our catalogue No. 70 contains all details of these instruments and will be gladly forwarded on request.

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

S

Symbol of Quality

GENERAL DESCRIPTION AND SPECIFICATIONS OF D.C. INSTRUMENTS

Our Models S, HS, C, J, and UNIVERSITY instruments comprise a line of D.C. precision microammeters, milliammeters, ammeters, millivoltmeters and voltmeters. They feature the highest degree of electrical efficiency. Such a characteristic is most desirable where it is necessary to have a low burden on the circuit to be measured. They are stable, accurate, rugged instruments whose high quality construction and performance assures the user of the finest in electrical indicating instruments.

GENERAL CONSTRUCTION AND PERFORMANCE CHARACTERISTICS

ASA SPECIFICATIONS — All instruments conform to ASA specification C-39.1—1951 for either .25% or .5% class portables.

TYPE—Double-pivoted D'arsonval.

MOVEMENT AND MAGNET — Large size formerless moving coil is light in weight and sturdy in construction. Magnet of Alnico 2 or 5 is engineered to give maximum flux density and stability. Unusual assembly guards against the possibility of long term drift.

PIVOTS AND JEWELS — All our instruments normally contain the finest quality high carbon steel pivots and sapphire jewels. Where high sensitivity is necessary, diamond pivots and shock mounted jewels are furnished. Your specific attention is called to "Diamond Pivots" which are available in any SRIC instrument if not already included in specifications, at an additional charge of $30.00. This is a revolutionary development in pivot construction, pioneered by our progressive engineering staff. "Diamond Pivots" will withstand the tremendous impact of a 3-foot drop in an instrument without deformation of either pivot or jewel. They are completely non-magnetic and free from hysteresis effects. "Diamond Pivots" are ground to a minimum riding surface of .0007 square inches. Their installation in any instrument assures the user of a virtually "friction free" moving element.

LEVELING—While these models are designed primarily for horizontal use, no precise leveling is necessary. It is recommended that they be used at no greater angle than 5° from the horizontal. Use of a horizontal type instrument at greater angles, dependent upon the sensitivity involved, reduces the repeatability of the instrument's indication due to pivot roll or change of position.

SCALES—All SRIC instruments are individually calibrated and their scales hand drawn. Scale plates are of heavy brass, and are finished in a durable white lacquer. In maintenance and repair, the scale lines may be easily erased many times and replaced without damage to the scale plate.

READABILITY—Instruments have knife-edge pointers and anti-parallax mirrors for maximum readability.

MAGNETIC AND ELECTROSTATIC SHIELDING—Most instruments contain magnetic and electrostatic shielding in conformance with ASA specifications.

Magnetic shielding not available in instruments with a sensitivity of 5 microamperes or below, or 200,000 ohms per volt and higher.

TEMPERATURE EFFECTS—Most instruments can be considered temperature compensated between 20°C and 30°C. Current and voltage measuring instruments have a temperature coefficient of ±.02% per degree centigrade or less. High sensitivity millivoltmeters tend to a somewhat higher temperature coefficient. Reference temperature is 25°C. This information is contained on data card enclosed in the individual instrument with cover giving corrective factor.

SWITCH CONTROLS—All three or more range instruments are normally supplied switch controlled. Good instrumentation design requires that ranges of 3 amperes or higher and less than 5 millivolts have separate binding posts. If binding posts only are desired, they can be substituted for the switch at no extra cost.

DAMPING—Accomplished by the use of eddy currents in the moving coil or shunting by external resistance.

ZERO ADJUSTMENT—Mechanically by bakelite knob on panel of models S, HS, C and J and slotted screw on University Models.

PACKING AND SHIPMENT OF INSTRUMENTS

After comprehensive tests, we have developed our own method of securely packing our Precision Electrical Instruments. The instrument "floats" completely surrounded in a cushion of two inch thick rubberized hair. In the case of our larger instruments such as the Universal Polyranger — or — our Electrostatic Voltmeters, etc., this size is increased to four inches thick.

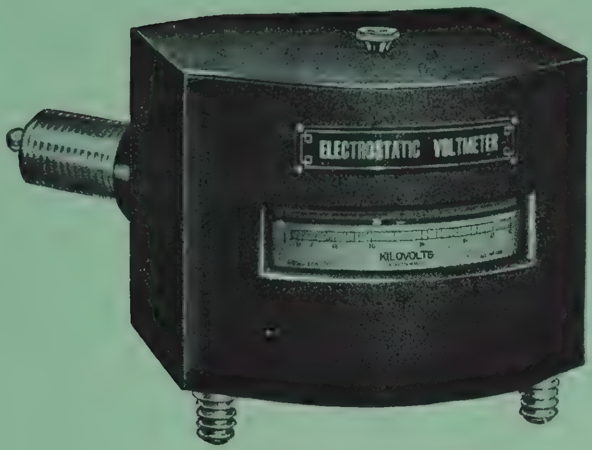
This method means that your new SENSITIVE RESEARCH instrument will arrive in perfect condition.

Incidentally, if you are really in a hurry for your instrument, may we suggest AIR EXPRESS and we will get it to the proper airport so you will receive same the next day anywhere in this country, or, in three days, anywhere in the world.

To insure no cost adjustment, DAMAGED INSTRUMENTS must be examined in the original container by the carrier and a joint inspection report filed.

ELECTROSTATIC VOLTMETERS

SUPPLIED WITH DIAMOND PIVOTS AND SHOCK MOUNTED JEWELS



30 KILOVOLT INSTRUMENT

By the use of a novel design internal high voltage switch, multiranges of voltages from 5,000 full scale volts up to 50,000 volts are obtained. It has a distinct advantage in that the capacity of the instrument decreases as the range increases. Briefly explained, the switch operating in successive "click" positions, moves the stator electrode AWAY from the rotor in predetermined positions. The voltmeter is not limited to A.C. but can be used over all its ranges on D.C. The capacity of its lowest range (5,000 volts) is approximately 30 mmfd, and is about 10 mmfd at 50 to 100 kilovolts.

Supplied in one, two, three or four ranges with selector switch — for D.C. or A.C. measurements.

ACCURACY 1% **MOVING VANE TYPE** **FREQUENCY** **Limited to the frequency at which the capacity current is 200 milliamperes maximum**

MODEL	**TYPE**	**SCALE LENGTH**	**SENSITIVITIES AVAILABLE**
ESH	**Bench**	**6 inches**	**Ranges from 5000 Volts up to 100,000** ***Volts for A.C. or D.C.*** **Supplied in Single, 2, 3 and 4 ranges up to 50,000 Volts** **100,000** ***Volts in single range only***
ESD	**Portable**	**5.2 inches**	**Ranges from 120 Volts to 6,000 Volts** ***In single range, accurate for A.C. or D.C.*** **Can be supplied in two or three ranges** ***for A.C. only***
UNIVERSITY	**Portable**	**4 inches**	**Ranges from 300 Volts to 5,000 Volts** ***In single range, accurate for A.C. or D.C.*** **Can be supplied in double ranges** ***for A.C. only***
EWESD-5	**Panel Mtg.**	**5.2 inches**	**Any Range from 120 Volts to 5,000 Volts** ***A.C. or D.C. Single range only***

LOW OR HIGH PEAK UNITS

PEAK UNITS

for use with above Electrostatic Voltmeters

Up to 30,000 volts on "positive" or "negative" peaks

Supplied in one, two or three ranges — from 120 volts to 6,000 volts.

A MODERN
PORTABLE ELECTROSTATIC VOLTMETER
MODEL ESD

DIRECT CURRENT

MICROAMMETERS – MILLIAMMETERS – AMMETERS

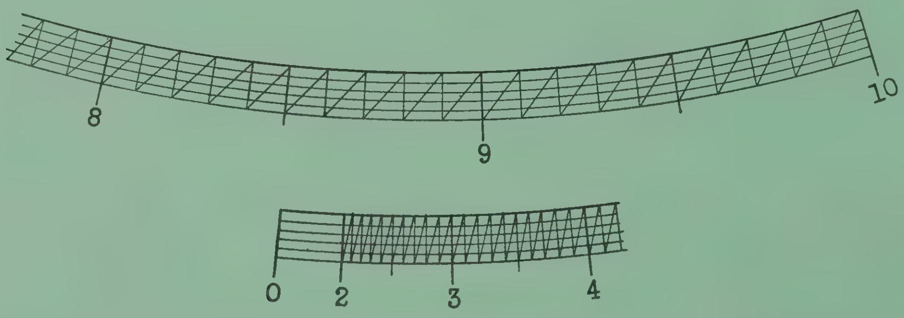
D'ARSONVAL MOVEMENT   FOR PANEL MOUNTING, SEE PAGE 15

MODEL	TYPE	ACCURACY	SCALE LENGTH	SENSITIVITIES AVAILABLE
*B	Lab. St'd	.1 of 1%	12 inches	*Any range from* 30 microamperes (full scale) to 50 amperes
*S	Portable	.5 of 1% & 1%	5.2 & 6.3 inches	1 microampere (full scale) to 1000 microamperes
*C	Portable	.25 of 1%	6.3 inches	30 microamperes (full scale) to 50 amperes
*J	Bench type	.5 of 1%	3¼ inches	1 microampere to 1000 microamperes
*UNIVERSITY	Portable	.5 of 1%	4 inches	2 microamperes to 10 amperes
*UP	Panel Mtg.	1%	4 inches	30 microamperes to 50 amperes
*UPP	Panel Mtg.	.5 of 1%	4 inches	200 mieroamperes to 50 amperes

**MULTIRANGE COMBINATIONS IN THESE MODELS ARE SUPPLIED IN EASILY READ OVERLAPPING RANGES.*

USING THESE BASIC SENSITIVITIES, MULTIRANGES CAN BE SUPPLIED USING THE 2-5-10 RATIO OR THE 3-7.5-15 RATIO, ALL INSTRUMENTS ARE COMPACT, USING OUR RUGGED, POSITIVE CLICK POSITION SELECTOR SWITCHES.

MOST OF THE LISTED INSTRUMENTS, WITH EXCEPTION OF ULTRA SENSITIVE RANGES, ARE SUPPLIED MAGNETICALLY SHIELDED. ALL SENSITIVE RANGES ARE SUPPLIED WITH DIAMOND PIVOTS—SEE CATALOG #70 FOR EXACT INFORMATION ON THE RANGES REQUIRED. ON THE MORE SENSITIVE RANGES, INSTRUMENTS ARE MADE IN HIGH OR LOW RESISTANCE TYPES.



Shown are full size sections of a typical vernier A.C. LABORATORY STANDARD scale

DIRECT CURRENT GALVANOMETERS

MODEL	TYPE	MOVEMENT	ACCURACY	SCALE LENGTH	SENSITIVITIES AVAILABLE
J	Bench	D'Arsonval	.5 of 1%	3¼ inches	.02 microampere per division and up
JD	Bench	Differential	.5 of 1%	3¼ inches	2—0—2 microamperes to 100—0—100 microamperes
JWG	Panel Mtg.	D'Arsonval	.5 of 1%	4 inches	15—0—15 microamperes to 100—0—100 microamperes

DIRECT CURRENT VOLTMETERS

FOR PANEL MOUNTING, SEE PAGE 15.

MODEL	TYPE	ACCURACY	SCALE LENGTH	SENSITIVITIES AVAILABLE
B	Lab. Std.	.1 or 1%	12 inches	*Two Multirange Combinations* 3/7.5/15/30/75/150/300/750 Volts 5/10/20/50/100/200/500/1000 Volts
*S	Portable	.5 of 1%	5.2 & 6.3 inches	Any Range from 0 - .5 to 1500 Volts *In sensitivities of* 5,000, 10,000, 20,000 or 50,000 *ohms per volt*
*C	Portable	.25 of 1%	6.3 inches	Any Range from 1 to 1500 Volts (1000 ohms per Volt)
*UNIVERSITY	Portable	.5 of 1%	4 inches	Any Range from 1 Volt to 750 Volts (1000 ohms per Volt)
*UPP	Panel Mtg.	.5 of 1%	4 inches	Any Range from 1 Volt to 1000 Volts (1000 ohms per Volt)
DCHI	Portable	1%	4 inches	0 - 3/7.5/15/30 Kilovolts

ULTRA HIGH RESISTANCE VOLTMETERS

HS	Portable	.5 of 1%	5.2 & 6.3 inches	Supplied with DIAMOND PIVOTS

Zero at Left	Zero at Center
10,000 *ohms per Volt* .005/.02/.1/.5/2/5/20/50/100 Volts	20,000 *ohms per Volt* .005/.02/.1/.5/2/5/20/50/100 Volts
50,000 *ohms per Volt* .02/.05/.1/.2/1/5/20/50 Volts	200,000 *ohms per Volt* .02/.05/.1/.2/1/5/10 Volts
100,000, 200,000 or 500,000 *ohms per Volt* .05/.1/.5/1/5/10 Volts	200,000, 500,000 or 1,000,000 *ohms per volt* .05/.1/.5/1/5/10 Volts

DIRECT CURRENT MILLIVOLTMETERS

B	Lab. Std.	.1 or 1%	12 inches	Ranges { 0—50 millivolts 0—50/100 millivolts
*S	Portable	.5 of 1%	6.3 inches	Any Range from 0—1 m.v. to 2000 millivolts
C	Portable	.25 of 1%	6.3 inches	Ranges { 0—50 millivolts 0—50/100 millivolts
J	Bench	.5 of 1%	3.2 inches	Ranges of 0—1, 2, 10 or 50 millivolts
*UNIVERSITY	Portable	.5 of 1%	4 inches	Any Range from 2 millivolts (full scale) up to 200 millivolts
UPP	Panel Mtg.	.5 of 1%	4 inches	Ranges { 0—50 millivolts 0—50/100 millivolts

**MULTIRANGE COMBINATIONS IN THESE MODELS ARE SUPPLIED IN EASILY READ OVERLAPPING RANGES.*

USING THESE BASIC SENSITIVITIES, MULTIRANGES CAN BE SUPPLIED USING THE 2-5-10 RATIO OR THE 3-7.5-15 RATIO, ALL INSTRUMENTS ARE COMPACT, USING OUR RUGGED, POSITIVE CLICK POSITION SELECTOR SWITCHES.

MOST OF THE LISTED INSTRUMENTS, WITH EXCEPTION OF ULTRA SENSITIVE RANGES, ARE SUPPLIED MAGNETICALLY SHIELDED. ALL SENSITIVE RANGES ARE SUPPLIED WITH DIAMOND PIVOTS—SEE CATALOG #70 FOR EXACT INFORMATION ON THE RANGES REQUIRED.

ALTERNATING CURRENT
MILLIAMMETERS AND AMMETERS

FOR PANEL MOUNTING INSTRUMENTS, SEE PAGE 15.

MODEL	TYPE	FREQUENCY	MOVEMENT	ACCURACY	Scale Length	SENSITIVITIES AVAILABLE
L	Lab. Std.	up to 133 cycles	Dynamometer	.1 or 1%	12 inches	*Supplied in double range* From 50 m.a. to 20 amperes
D	Portable	up to 2500 cycles according to range	Dynamometer	.25 of 1%	6.3 inches	*Supplied in double range* From 5 m.a. to 1000 m.a.
UNIVERSITY	Portable	up to 133 cycles	Dynamometer	.5 of 1%	4 inches	From 10 m.a. to 1000 m.a. *Single or double ranges*
MI	Portable	25—500 cycles	Moving Iron	.5 of 1%	6.3 inches	From 10 m.a. to 20 amperes *Single or double ranges*
*A	Portable	up to 1,000,000 cycles	Thermo	.75 of 1%	6.3 inches	From 1 m.a. to 1000 m.a. *Multirange frequency 15000 cycles*
*AU	Portable	up to 20,000 cycles	Thermo	.75 of 1%	6.3 inches	From 1.5 m.a. to 1000 m.a.
*RF	Portable	up to 1,000,000 cycles	Thermo	.75 of 1%	6.3 inches	From 0—1 m.a. to 1000 m.a. *Separate thermo couple for each range*
XT	Portable	up to 70 megacycles	Air Thermo	1%	6.3 inches	From 0—2 amperes to 100 amperes *Single range only*

**MULTIRANGE COMBINATIONS IN THESE MODELS ARE SUPPLIED IN EASILY READ OVERLAPPING RANGES.*

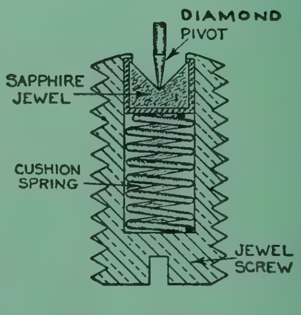
USING THESE BASIC SENSITIVITIES, MULTIRANGES CAN BE SUPPLIED USING THE 2-5-10 RATIO OR THE 3-7.5-15 RATIO, ALL INSTRUMENTS ARE COMPACT, USING OUR RUGGED, POSITIVE CLICK POSITION SELECTOR SWITCHES.

MOST OF THE LISTED INSTRUMENTS, WITH EXCEPTION OF ULTRA SENSITIVE RANGES, ARE SUPPLIED MAGNETICALLY SHIELDED. ALL SENSITIVE RANGES ARE SUPPLIED WITH DIAMOND PIVOTS—SEE CATALOG #70 FOR EXACT INFORMATION ON THE RANGES REQUIRED.

"DIAMOND PIVOTS" and SHOCK MOUNTED SAPPHIRE JEWELS

SRIC has long pioneered in the field of highly accurate electrically efficient indicating instruments.

This constant engineering progress now enables us to offer one of the most advanced developments of the past decade in double pivot instruments—*THE DIAMOND PIVOT AND SHOCK MOUNTED SAPPHIRE JEWEL.* This unique assembly will withstand a 200 G drop test without deformation of either pivot or jewel. The diamond pivot has a riding surface of .0008" which insures a virtually "friction free" moving element, with no manual "tapping" necessary for repeatability. It is offered as an accessory feature in many SRIC instruments (specify "Diamond Pivots" and add $30 to listed price). However, the more sensitive, weaker torque instruments are fitted with diamond pivots and shock mounted jewels as standard equipment. These are illustrated in the pages of the respective instruments, in Catalog No. 70.



SHOCK MOUNTED SAPPHIRE JEWEL

ALTERNATING CURRENT VOLTMETERS

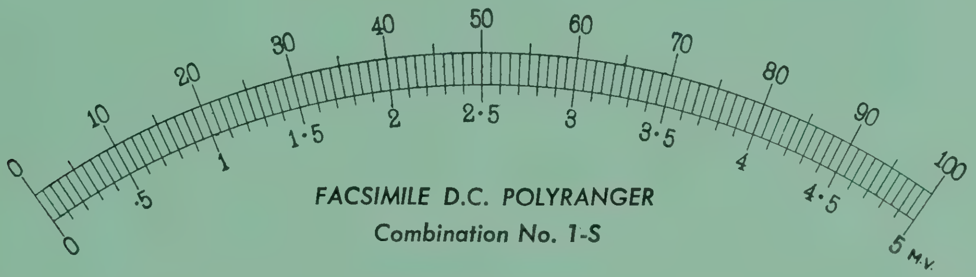
FOR PANEL MOUNTING, SEE PAGE 15.

MODEL	TYPE	FREQUENCY	MOVEMENT	ACCURACY	SCALE LENGTH	SENSITIVITIES AVAILABLE
						Any range from
L	Lab. St'd	up to 133 cycles	Dynamometer	.1 of 1%	12 inches	75 Volts to 1000 Volts
*D	Portable	**up to 133 cycles	Dynamometer	.25 of 1%	6.3 inches	1.5 Volts to 1000 Volts
*UNIVERSITY	Portable	**up to 133 cycles	Dynamometer	.5 of 1%	4 inches	30 Volts to 750 Volts
*A	Portable	up to 7000 cycles	Thermo	.75 of 1%	6.3 inches	.2 Volt (full scale) to 1000 Volts 100 *and* 500 *ohms per Volt*
*UNIVERSITY	Portable	up to 7000 cycles	Thermo	.75 of 1%	4 inches	.2 Volt to 750 Volts 100 *and* 500 *ohms per Volt*
MI	Portable	up to 125 cycles	Mov. Iron	.5 of 1%	6.3 inches	7.5 Volts to 750 Volts

**MULTIRANGE COMBINATIONS IN THESE MODELS ARE SUPPLIED IN EASILY READ OVERLAPPING RANGES.*

USING THESE BASIC SENSITIVITIES, MULTIRANGES CAN BE SUPPLIED USING THE 2-5-10 RATIO OR THE 3-7.5-15 RATIO, ALL INSTRUMENTS ARE COMPACT, USING OUR RUGGED, POSITIVE CLICK POSITION SELECTOR SWITCHES.

**Up to 3 volts, 70 cycles only. From 7.5 to 1000 volts, up to 1000 cycles. From 15 to 1000 volts, up to 2500 cycles.



FACSIMILE D.C. POLYRANGER
Combination No. 1-S

HAND DRAWN SCALE

ALTERNATING CURRENT INSTRUMENTS

DYNAMOMETERS

The dynomometer is the best choice if you need extreme accuracy, ruggedness, and stability but you must be willing to sacrifice sensitivity to get these characteristics. This type is the most acceptable for all sorts of standardization work and their calibration can be checked on direct current if necessary by simply taking an average of its readings on both polarities.

THERMOCOUPLE INSTRUMENTS

Thermocouple instruments have somewhat lower accuracies but are capable of much higher sensitivities. Thermocouples give high accuracies at high frequencies. In fact, they are the only accurate method of measuring current at A.F. and R.F. frequencies. Please do not forget that thermocouples are fragile by the very nature of their construction and will withstand overloads of only 100% in excess of their rated heater currents. They also have a negative temperature coefficient of approximately .2 to 1% per degree centigrade. When ordering a thermocouple instrument note that SENSITIVE RESEARCH thermocouple instruments may be purchased with a safety shunt allowing an overload of 1000% of rated current, and can be supplied to include AUTOMATIC TEMPERATURE COMPENSATION. In addition, should an accidental burnout occur, a thermocouple replacement feature is available that will allow you to replace the thermocouple yourself. Matched replacement thermocouples can be shipped from stock and your instrument will consequently see little loss of valuable service. Remember that SENSITIVE RESEARCH thermocouple instruments will check equally well on A.C. or D.C.

MOVING IRON INSTRUMENTS

Our third A.C. instrument is the popular MOVING IRON type. The accuracy of this design is not as great as can be obtained with the dynamometer, nor the sensitivity as good as the thermocouple instrument. They are a rugged, reliable instrument capable of withstanding large overloads while maintaining a satisfactory accuracy for long periods of time and, of course, at a more moderate price than either of the previously mentioned types.

SELF CHECKING DIRECT CURRENT VOLT-AMP-MILLIAMMETER

SUPPLIED WITH DIAMOND PIVOTS AND SHOCK MOUNTED JEWELS

MODEL BS
SCALE LENGTH 12 INCHES

Fitted with Dust Cover

MEASURES WITH AN

ACCURACY OF .05 OF ONE PER CENT
1.5 MILLIAMPERE to 15 AMPERES
LOWEST SCALE DIVISION 15 MICROAMPERES

300 MILLIVOLTS to 1500 VOLTS
LOWEST SCALE DIVISION 3 MILLIVOLTS
CALIBRATED IN ABSOLUTE UNITS (ABS SYSTEM)

	Full Scale Values	**Code**	**Price**
Current	1.5/3/7.5/15/30/75/150/300/750 M.A. & 1.5/3/7.5/15 Amperes	SELFCHECK	$1825.00
Voltage	.3/.75/1.5/3/7.5/15/30/75/150/300/750/1500 Volts	(Supplied with Dust Cover)	
	Replacement standard cells with necessary standard resistance..		50.00

SELF CHECKING A.C.-D.C. STANDARD VOLT-AMP-MILLIAMMETER

SCALE 6.3 INCHES

MODEL THACH

MEASURES DIRECTLY

A.C. or D.C. CURRENT
FROM 10 MILLIAMPERES TO 5 AMPERES
(lowest reading 2 milliamperes)

and

A.C. or D.C. VOLTAGE
FROM 1 VOLT TO 1000 VOLTS
(lowest reading 200 millivolts)

D.C. TO 4000 CYCLES
ACCURACY .2 OF 1%

FOR USE ON A.C. or D.C.
1% UP TO 15000 CYCLES

Combination 1-X

	Full Scale Ranges	Code	Price
Current	0—10/20/50/100/200/500/1000 m.a. 2/5 amperes	CHEKALAB (Standard Model) single thermocouple	$975.00
Volts	0—1/2/5/10/20/50/100/200/500/1000 volts	DELABACHEK (DELUXE MODEL) two thermocouples	1075.00

Combination 2-X

	Full Scale Ranges	Code	Price
Current	0—15/30/75/150/300/750 m.a. & 1.5/3 amperes	ACCURCHEK (Standard Model) single thermocouple	$875.00
Volts	0—1.5/3/7.5/15/30/75/150/300/750 volts	ACCURMETER (DELUXE MODEL) two thermocouples	975.00

(Both of above supplied with dust cover)

Replacement thermocouples (with correction data to original accuracy)	each	$75.00
Replacement standard cell with necessary resistance and statement of its absolute voltage..........................	each	45.00

LABORATORY STANDARD DYNAMOMETER

MODEL DYL

SCALE LENGTH 12 INCHES

ACCURACY .1 OF 1%

		FREQUENCY	*CODE*	*PRICE*
10/20/50/100/200/500 MILLIAMPERES 1/2/5/10 AMPERES 10/20/50/100/200/500 VOLTS	16 SELF CONTAINED RANGES	50-70 CYCLES	DYNLAB	$1780.00
10/20/50/100/200/500 MILLIAMPERES 1/2/5/10 AMPERES 20/50/100/200/500 VOLTS	15 SELF CONTAINED RANGES	380-420 CYCLES	DYNFRE	$2280.00

"POLYRANGERS" are our standard multirange *combination instruments* all compact in one case.

D. C. POLYRANGERS

MAGNETICALLY SHIELDED *SUPPLIED WITH DIAMOND PIVOTS*

Model S Portable Scale length 5.2" Accuracy .5 of 1% D'Arsonval type

TWO DIFFERENT COMBINATIONS OF RANGES ON MODELS S, C AND UNIVERSITY:

Comb. 1-S
.1/1/10/100/1000 m.a.
.005/.01/.05/.1/1/10/100/1000 Volts
(1000 *ohms per volt*)

Comb. 2-S
.2/2/20/200/2000 m.a.
.005/.01/.02/.1/.2/2/20/200 Volts
(5000 *ohms per volt*)

Model C Portable Scale length 6.3" Accuracy .25 of 1% D'Arsonval type

Comb. 3-C
1.5/3/7.5/30/75/300/750/3000 m.a.
3/15/30/150/300/750 Volts
(1000 *ohms per volt*)

Comb. 4-C
10/50/100/500/1000 m.a.—5/10 amps.
1/5/10/50/100/500/1000 Volts
(1000 *ohms per volt*)

University Model Portable Scale length 4" Accuracy .5 of 1% D'Arsonval type

Comb. 1-UD
.1/1/10/100/1000 m.a.
2/20/200/500 Volts
(1000 *ohms per volt*)

Comb. 2-UD
.2/2/20/200/2000 m.a.
2/20/200/500 Volts
(1000 *ohms per volt*)

UNIVERSAL POLYRANGERS

Model USP Portable Scale length 5.2" Accuracy .5 of 1% for D.C. .75 of 1% for A.C.

D'Arsonval type for D.C. Thermo-couple type for A.C. Frequency up to 7000 cycles

D.C. Ranges
.2/2/20/200/1000/2000 m.a.
.005/.05/.1/.5/2/20/200/1000 Volts
(5000 *ohms per volt*)

A.C. Ranges
15/30/150/300/1500/3000 m.a.
.3/1.5/3/15/30/150/300/750 Volts
(100 *ohms per volt*)

Model U-88 Portable Scale length 5.2" Accuracy .5% D.C. .75% A.C.

88 RANGES IN CURRENT AND VOLTS IN EASY OVERLAPPING SCALES:

Will measure from 200 microamperes to 1.5 amperes in D.C.
10 milliamperes to 3 amperes in A.C.

and

Will measure from 20 millivolts to 750 volts in D.C.
.5 volt to 750 volts in A.C.

5000 *ohms per volt D.C.* 100 *ohms per volt A.C.*

A. C. OR D. C. POLYRANGERS

Model A Portable Scale length 5.2" Accuracy .75 of 1% to 7,000 cycle—volts 18,000 cycles—current Thermo-couple type

THREE DIFFERENT COMBINATIONS OF CURRENT AND VOLTAGE AS FOLLOWS:

Comb. 1-A
10/50/100/500/1000/5000 m.a.
.5/1/5/10/50/100/500/1000 Volts
(100 *ohms per volt*)

Comb. 2-A
2/10/50/200/500/1000 m.a.
2/10/50/200/500 Volts
(500 *ohms per volt*)

Comb. 3-A
15/50/150/500/1500/5000 m.a.
.5/1.5/5/15/50/150/500/1500 Volts
(100 *ohms per volt*)

DYNAMOMETER POLYRANGERS

Model DYP Portable for 50—70 cycles only Scale length 6.3" .3 of 1% Accuracy

TWO DIFFERENT COMBINATIONS OF CURRENT AND VOLTAGE AS FOLLOWS:

Code DYNASP
5/10/20/50/100/200/500 m.a.—1/2/5/10 amperes
5/10/20/50/100/200/500/1000/2000 Volts

Code DYNAMO
10/30/100/300 m.a.—1/3/10 amperes
10/30/100/300/1000 Volts

A. C. - D. C. VOLT AMMETER

Model UVA Portable Scale length 4" Accuracy .5 of 1% on D.C. .75 of 1% on A.C.

Moving Iron Design for A.C. Twin Model Design D'Arsonval type for D.C.

Ranges on D.C.
1/10/100 m.a.—1/10 amperes
.05/.1/1/10/100/1000 Volts
(1000 *ohms per volt*)

Ranges on A.C.
10/50/100/500 m.a.—1/5/10 amperes
10/50/150/500 Volts
(50-60 *cycle only*)

WILLIAMSON D. C. VOLT-AMMETER

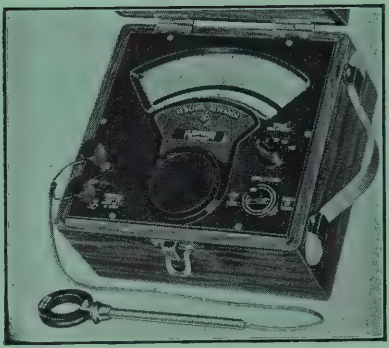
Model WVA Portable Scale length 6.3" Accuracy .25%

27 RANGES IN CURRENT AND VOLTS

Current with ranges from 0 - 1/1.5/3/7.5/15/30/75/150/300/750 m.a.—1.5/3/7.5/15 amperes
Voltage with ranges from 0 - .1/.15/.3/.75/1.5/3/7.5/15/30/75/150/300/1000 Volts

SPECIAL INSTRUMENTS

FOR PANEL MOUNTING, SEE PAGE 15.



FLUXMETERS

An integrating instrument without restoring torque. Primarily for the measurement of flux linkage by means of search coils. Single range instruments (Model FS) from 10,000 maxwells per division to 1,000,000 maxwells per division on zero center, 50 division scales. $195.00. Multirange instrument (Model FM) covers full range of all above at $285.00. .5% accuracy. 5.2" scale.

RATIOMETERS

A crossed coil type of instrument indicating the ratio of two currents in independent insulated circuits. Multirange giving satisfactory indications over the range of 50 microamperes to 1 ampere. $295.00. 1% accuracy at minimum current, .25% at maximum. 5.2" scale.

DIFFERENTIAL INSTRUMENTS

Two separate coils in a single movement, with circuits insulated from each other for 300 volts. Coils will carry from 50 times (highest sensitivity models) to 10 times (high current models) the normal full scale current. Indicates the sum or difference of the currents in each coil depending on external connections. Ranges from 1 - 0 - 1 microamperes in Model JD (3¼" scale) and from 2 - 0 - 2 microamperes in the Model SD (5.2" scale) up to 500 - 0 - 500 milliamperes. Also from 1.5 - 0 - 1.5 millivolts to 100 - 0 - 100 millivolts. Model JD $173.00 to $193.00 Model SD $223.00 to $241.00. Dual range instruments available in Model SD only. Prices on application. .5% accuracy.

POTENTIOMETER VOLTMETERS

An instrument with a self contained battery supply, indicating instrument and galvanometer. For the measurement of potentials without drawing current from the source. Very useful for corrosion studies and measurements similar high or unknown impedance circuits. Multirange instruments available in many combinations, with a high sensitivity of 2 millivolts full scale and up to 20 volts. $285.00 to $338.00. ⅓% accuracy. 5.2" scale.

ZERO RESISTANCE INSTRUMENTS

An instrument similar to the potentiometer voltmeter, with self contained battery supply, indicating meter and galvanometer. For the measurement of currents without introducing a voltage drop in the circuit. Multirange instruments available in many combinations, highest sensitivity 10 microamperes and up to 300 milliamperes. $310.00 to $335.00. .5% accuracy. 5.2" scale.

MUTUAL CONDUCTANCE INSTRUMENTS

Dynamometer type instruments with signal voltages and current sensitivities for the measurement of Gm by $\Delta Ip/\Delta Eg$ and for measuring plate impedance by $\Delta Ep/\Delta Ip$. Single range instruments for Gm in ranges of 50 micromhos to 100,000 micromhos at $210.00. Multirange instruments within the above limits from $280.00 to $340.00. Also combined Gm and Rp instruments in two combinations at $375.00. .5% accuracy. 5.2" scale.

THERMO COUPLES IN VACUUM

Ranges from 1 milliampere to 1000 milliamperes (full scale) can be supplied immediately. Unmounted or mounted in case. Isolated type for U.H.F. measurements in same ranges can be supplied.

SPECIAL INSTRUMENTS

FOR PANEL MOUNTING, SEE PAGE 15.

REFERENCE STANDARD WATTMETERS

High accuracy dynamometer wattmeters available in standard designs for the measurement of power at frequencies to 800 cycles and with power factors of 50% or higher to an accuracy of ¼%. Ranges available from 5 watts to 2000 watts at $265.00 to $298.00.

Low power factor instruments for use at power factors of 20% and higher are available for use up to 500 cycles with an accuracy of ½%. These instruments are designed to stand the high currents involved in such measurements without damage. Ranges from .2 watt to 3000 watts at a cost of $270.00 to $322.00. Scale length 6.3 inches.

UNIVERSITY MODEL WATTMETERS

Wattmeters in the moderately priced UNIVERSITY line are available in the same ranges as the Reference Standard series. Accuracy of the standard instruments is ½% and of the low power factor models ¾%. Prices from $170.00 to $205.00. Scale length 4 inches.

POLYPHASE WATTMETERS

Polyphase wattmeters for the measurement of two and three phase power are available in the Reference Standard series of instruments. These instruments use two dynamometer movements on a common shaft with the movements carefully matched for the utmost in accuracy. Standard units range from 15 to 2000 watts with an accuracy of ½%. Low power factor units are available for use down to 20% power factor in ranges from 1 watt to 1000 watts at an accuracy of ¾%. Prices are from $550.00 to $615.00. Scale length is 6.3 inches.

VOLT-AMP-WATTMETERS

This is a Reference Standard self contained instrument for the measurement of voltage, current and power. This instrument can be used separately as either a voltmeter, ammeter or wattmeter. In normal use for measuring the characteristics of a load the readings are all direct without the necessity of correction for instrument losses and the insertion losses are constant regardless of the parameter being read. Ranges from 25 to 500 volts, from .5 to 10 amperes and 12.5 to 5000 watts for use at 50 - 133 cycles, cost $405.00.

Also available for 50 - 800 cycle use with ranges of 100 to 500 volts, .5 to 10 amperes and 50 to 5000 watts at $430.00.

CURRENT PRODUCT

A dynamometer instrument with field coils and moving coil in separate circuits. The indication is proportional to the product of the currents in the two coils times the cosine of the phase angle between the two currents. Usable on DC or AC (25 - 500 cycles). Available in many combinations from .000025 milliamperes squared up. From $280.00 to $310.00. .25% accuracy. 5.2" scale.

FLUX VOLTMETERS

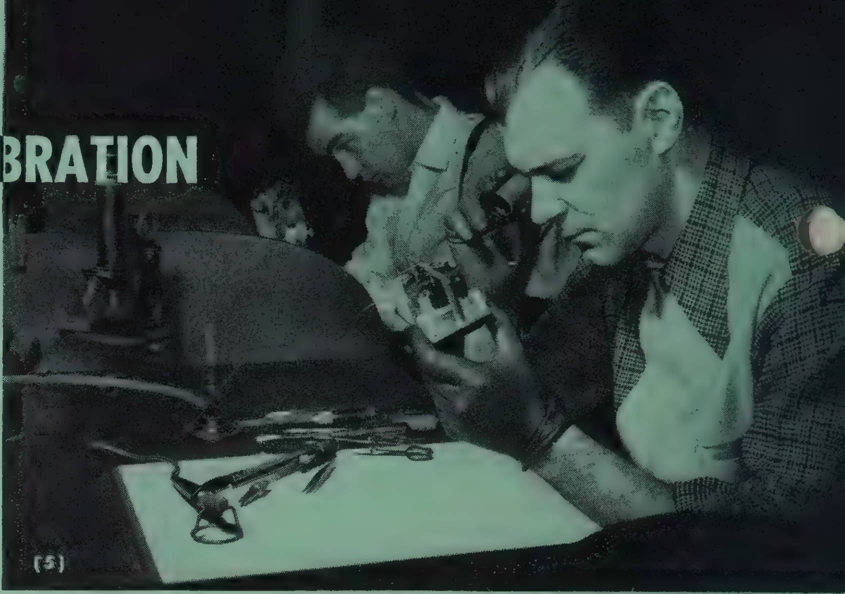
Rectifier type voltmeters with full wave germanium diode rectifiers. The instrument responds to the average of the impressed voltage, calibrations is 1.11 times average. For a pure sine wave indications equal RMS values. Used for determination of B_{max} from the induced voltage in magnetic measurements. Available in several combinations from 5 volts to 300 volts and in 1000 ohms per volt and 3333 ohms per volt models. $220.00 to $340.00. .5% accuracy. 6.3" scale. ¼% accuracy available at $75.00 additional.

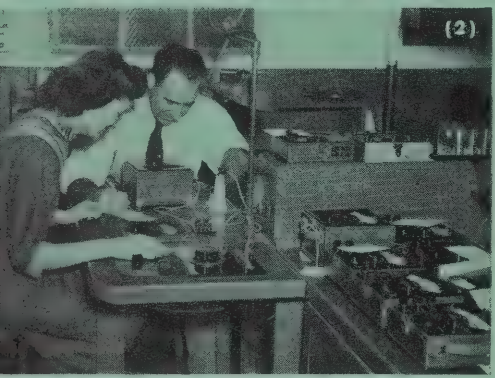
FREQUENCY METERS

A saturable reactor type of frequency meter. Normal input 115 volts ± 15%. Operation is relatively unaffected by waveforms. Available in wide range instruments with scale starting at 0 and in narrow range instruments centered around the more popular frequencies. Frequencies up to 1000 cycles. $325.00 to $425.00. ¼% accuracy. 6.3" scale.

INSTRUMENTS IN ASSEMBLY & CALIBRATION

(1)


(5)


(2)

(3)

(1) All Sensitive Research instruments are vacuum cleaned just before the panel is screwed down for the last time.

(2) Dynamometer Standards are used to calibrate our Electrostatic Voltmeters.

(3) Two operator method of calibrating a 1/20 of 1% D.C. laboratory standard instrument.

(4) Standard solenoid and mutual inductance methods are used to calibrate our fluxmeters.

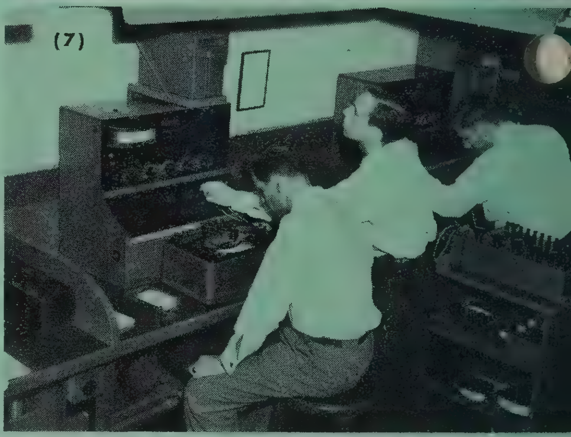
(5) Electrostatic Voltmeter movements are finally assembled using gloved hands to prevent contamination of the rotor and stator plates.

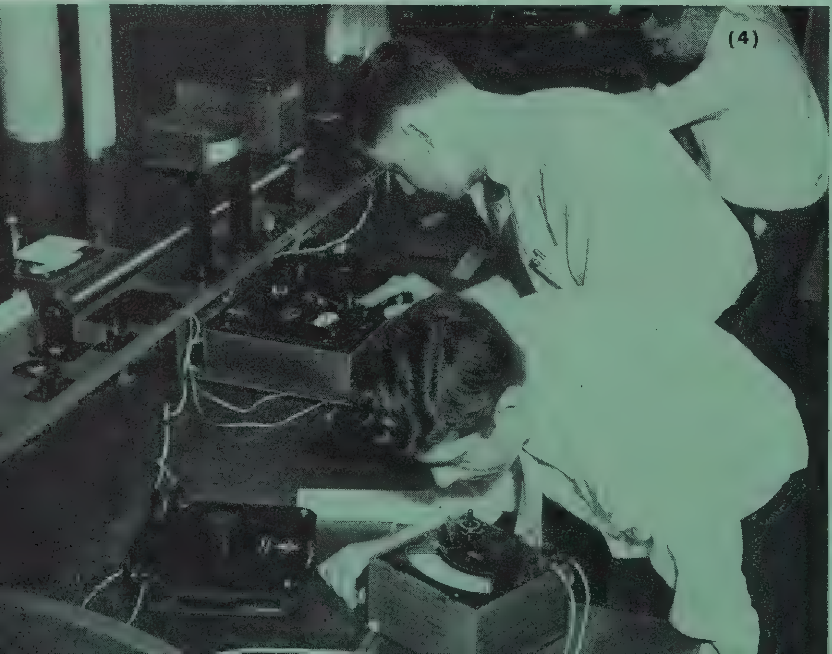
(6) Instrument scales are placed in position by skilled operators in an air-conditioned, dust free atmosphere.

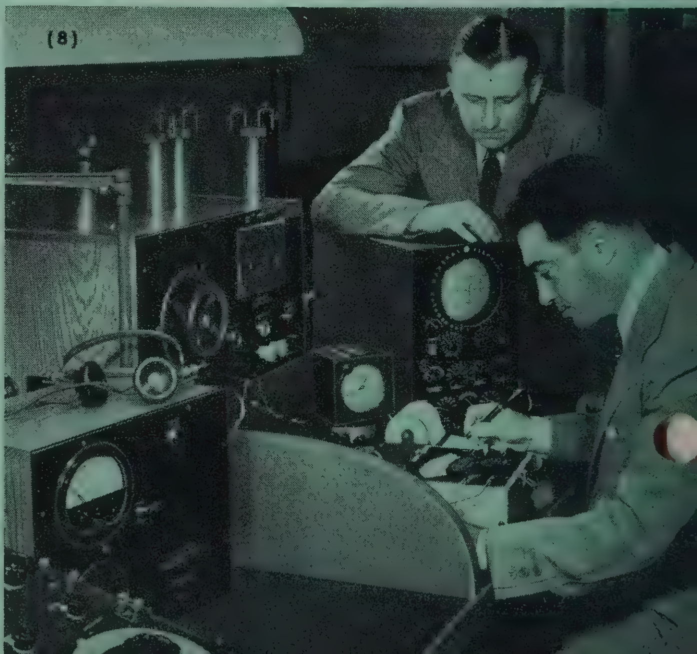
(7) Three operators are used to calibrate our Self Checking A.C. Standard instruments against standard potentiometers.

(8) Research on new designs is a full time activity in our Engineering Department.

(6)


(7)


(4)


(8)

TEST SETS—SHUNTS—STANDARD CELLS

MAGNETIC TEST SET

All of the necessary instruments for magnetic tests on soft magnetic materials assembled in a single case. All instruments available with separate terminals for individual use. All ASTM AC core loss and permeability tests can be made with the RMS voltmeter, flux voltmeter, RMS current meter and the wattmeter. For DC tests there is included a DC ammeter-milliammeter and a fluxmeter. Cost of the test set is $2650.00. Also available are Epstein frames and Mutual Inductors per ASTM specifications.

CORE LOSS TEST SET

This test set is designed specifically for rapid, high accuracy core loss tests to ASTM specifications. A long scale Flux & RMS type voltmeter is furnished for accurate setting of flux density. The RMS ammeter-milliammeter and the wattmeter are internally compensated for instrument losses so that all core loss readings are made without corrections. All core loss circuit connections are made internally and requires only connections to the sample and to the power source. Cost $1590.00.

DC TEST SETS

A complete DC test laboratory in a single case. Contains 3 basic instrument movements with shunts and multipliers to make almost any voltmeter or ammeter-milliammeter that is required. Also contains a sensitive galvanometer for special circuit uses together with a four dial decade resistance to 1111 ohms. Infinite flexibility for DC instrumentation experiments and wide range general usage. This test set is capable of creating over 200 separate instruments. Cost $800.00.

AC TEST SETS

An alternating current test set for the measurement of voltage, current and power. All models have full scale current ranges from 10 milliamperes to 10 amperes, full scale volt ranges from 30 volts to 300 volts and watt ranges from 5 watts to 2000 watts. All instruments switch controlled and with individual connections on front panel. Models for 50-70 cycle use, for 50-400 cycle use and for DC to 1000 cycle use at prices from $775.00 to $950.00.

CURRENT SHUNTS

Precision current shunts are available for use with 50 or 100 or 300 millivolt instruments and in current ranges from 1 to 1000 amperes. All are .1% accuracy. From $44.00 to $512.00. Available with .05% accuracy at 50% increase in price.

VOLTAGE MULTIPLIERS

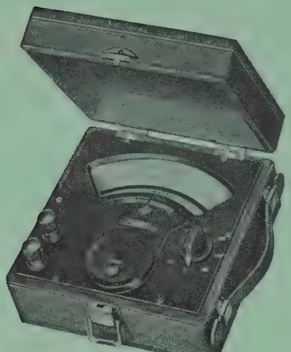
Multiplier resistors for range extension of any of our standard instruments are available. Size and price vary widely depending on the current drain of the instrument and the range extension in volts. .1% accuracy.

STANDARD CELLS *(MINIATURE SIZE)*

Unsaturated type standard cells (voltage 1.0188 to 1.0198) available either unmounted or mounted. Negligible temperature coefficient. .025% accuracy. Unmounted $20.00. Mounted $30.00. Replacement cells complete with current monitor resistors for replacement in our Self-Check instruments, $45 for AC instruments, $50 for DC instruments.

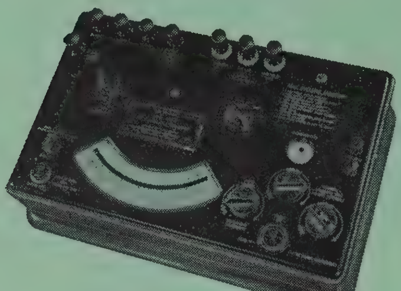
SIZES — MODELS — WEIGHTS

MODELS S, C, A, AU, RF, MI,
XT, HS, SD, FLV



SIZE: 8" x 7½" x 4½"
SCALE: 6.3" and 5.2"
WEIGHT: 7 lbs.

MODEL THACH



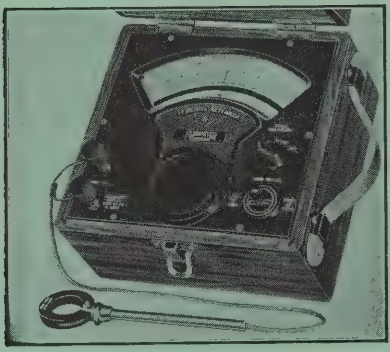
SIZE: 16⅜" x 10½" x 8¾"
SCALE. 6.3"
WEIGHT: 21 lbs.

MODEL UPP

MILLIAMPERES

SIZE: 5 9/16" x 5 3/8" x 3"
SCALE: 4"
WEIGHT: 4 lbs.

MODELS: D, DW, DLW, ESD, RA, GM,
FM, FS, PDW, DYSP, FRE

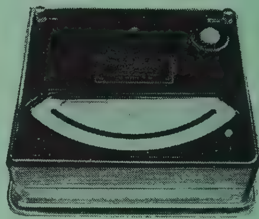


SIZE: 8" x 7½" x 6"
SCALE: 5.2" and 6.3"
WEIGHT: 8 lbs.

MODELS DCHI, U88, USP, DYP, ZR, PV, UVA, WVA

SIZE: 13¾" x 7½" x 6½"
SCALE: 5.2" and 6.3"
WEIGHT: 10 lbs.

MODELS L, B AND DYL



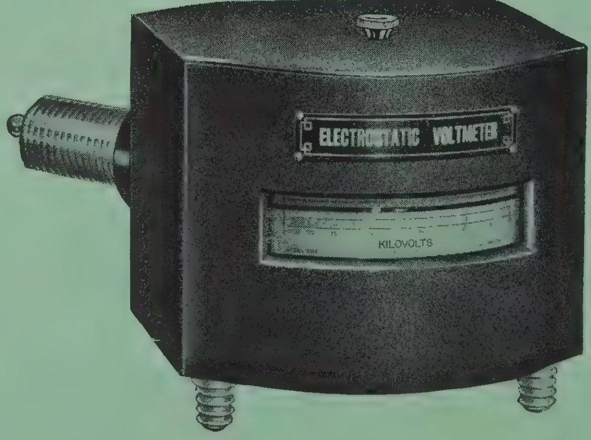
SIZE: 16⅛" x 14¼" x 6¼"
SCALE 12"
WEIGHT: 17 lbs.

UNIVERSITY MODEL

MILLIAMPERES
DIRECT CURRENT
SENSITIVE RESEARCH

SIZE: 5 9/16" x 5 3/8" x 3"
SCALE: 4"
WEIGHT: 3 3/4 lbs.

MODEL ESH


ELECTROSTATIC VOLTMETER
KILOVOLTS

SIZE: 17" x 12" x 9"
SCALE: 6"
WEIGHT: 18 lbs.

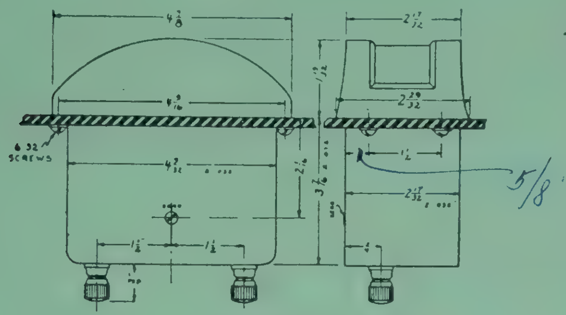
MODEL "UNIVERSITY" FOR
DYNAMOMETERS
WATTMETERS
ELECTROSTATICS

SIZE: 5¼" x 5" x 4⅜"
SCALE: 4"
WEIGHT: 5 lbs.

MOUNTING DIMENSIONS

For "Sensitive Research" Edgewise Panel Cases

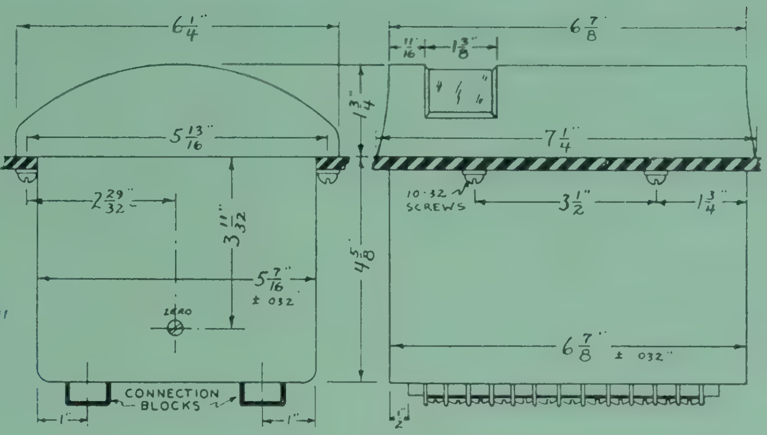
Practically all D.C. and Thermal instruments can be internally switch controlled up to 8 ranges. The switch has 8 positions.



4 3/8
2 11/32
4 9/16
2 29/32
6-32 SCREWS
4 9/32
1 1/2
1 1/2
5/8"

JW4 PANEL CASE

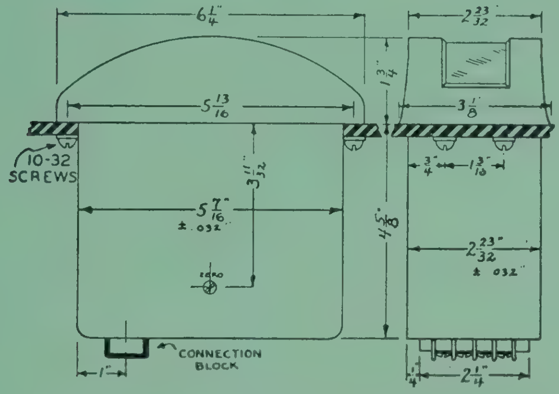
FOR MODELS JW, JDJW, JWV, JWG



6 1/4"
6 7/8
11/16"
1 3/8"
1 3/4"
7 1/4"
5 13/16"
2 29/32"
3 11/32"
5 7/16"
± 032
ZERO
10-32 SCREWS
3 1/2"
1 3/4"
4 5/8"
6 7/8"
± 032"
CONNECTION BLOCKS
1"
1"
1/2"

PDWEW "5" CASE

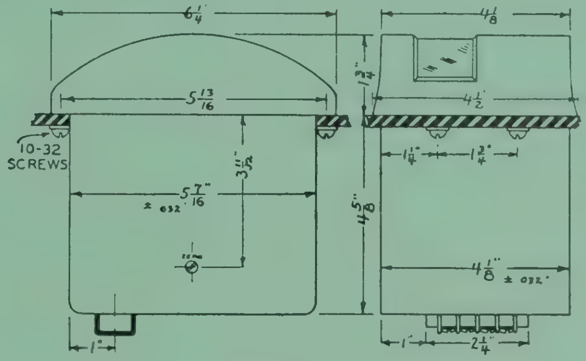
FOR MODEL PDW ANDPDLW (3 phase wattmeters)



6 1/4"
2 23/32
1 3/4"
5 13/16
3 1/8
10-32 SCREWS
3 11/32
5 7/16"
± .032"
3/4"
1 3/16
4 5/8"
2 23/32"
± 032"
ZERO
CONNECTION BLOCK
1"
1/4"
2 1/4"

EW5 SHALLOW CASE

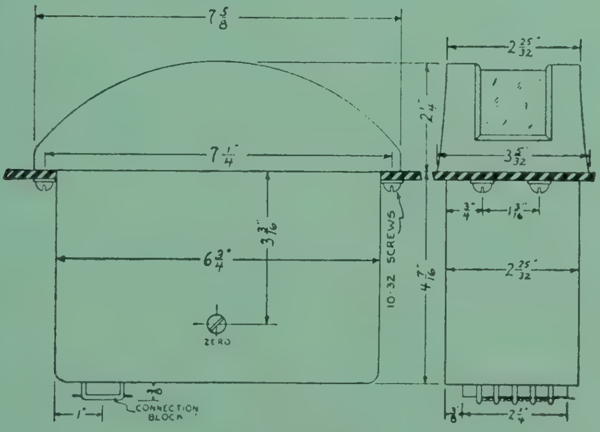
FOR MODELS S, A, HS, MI, FS, FM, SD, RA, FRE, AU, XT, RF AND FLV



6 1/4"
4 1/8
1 3/4"
5 13/16
4 1/2
10-32 SCREWS
3 11/32
5 7/16"
± 032
1 1/4"
1 3/4"
4 5/8"
4 1/8"
± 032"
ZERO
1"
2 1/4"

EW5 DEEP CASE

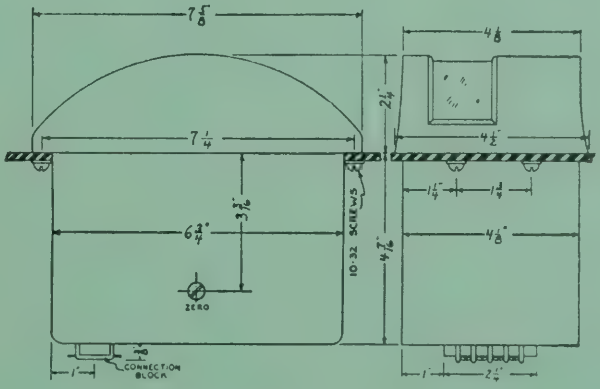
FOR MODELS D, DLW, DW, ESD, GM AND DYSP



7 5/8
2 25/32
2 1/4"
7 1/4"
3 5/32
3/4"
1 3/16"
3 7/16
6 3/4"
10-32 SCREWS
4 7/16
2 25/32"
ZERO
CONNECTION BLOCK
1"
1/4"
2 1/4"

EW7 SHALLOW CASE

FOR MODELS C, FLV, MI, FS, FM, RA AND FRE



7 5/8
4 1/8
2 1/4"
7 1/4
4 1/2
1 1/4"
1 3/4
3 7/16
6 3/4"
4 1/8"
10-32 SCREWS
4 7/16
ZERO
CONNECTION BLOCK
1"
2 1/4"

EW7 DEEP CASE

FOR MODELS DW, D, DYSP

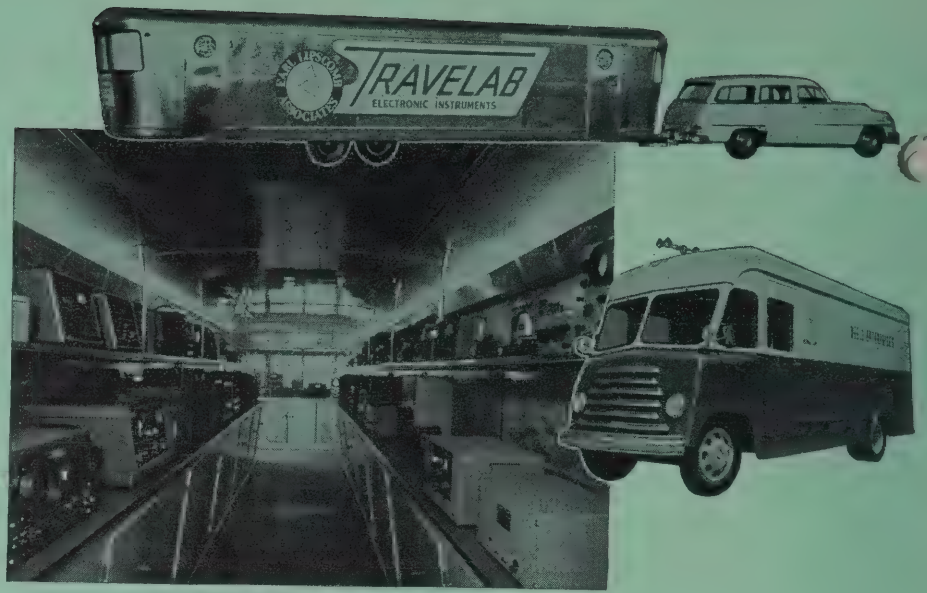
No Dynamometer Wattmeters or Current instruments can be internally switch controlled.

ACCURACIES IN THIS DESIGN CASE ARE THE SAME AS LISTED IN REGULAR MODEL PORTABLE INSTRUMENT.

NOTE: DUE TO SPACE LIMITATIONS, NO SAFETY KEY OR THERMOCOUPLE REPLACEMENT FEATURE IS AVAILABLE ON THE NEW EDGEWISE PANEL INSTRUMENTS.

"SENSITIVE RESEARCH" FIELD ENGINEERING REPRESENTATIVES

HOME OFFICE
310 MAIN ST., NEW ROCHELLE, N. Y.
BEverly 5-2300



TYPICAL INTERIOR

EXPORT

AD. AURIEMA, INC.
85 Broad Street
New York 4, New York
Bowling Green 9-7750

BELGIUM, HOLLAND & LUXEMBOURG

Electrophysique S. A.
Radio City P.O. Box 463
New York 19, N. Y.

CANADA

MEASUREMENT ENGINEERING LTD.
Arnprior, Ontario, Canada
Arnprior 400

Central Ontario Branch Off.
P.O. Box 50, Don Mills
Toronto, Ontario
Hickory 4-8172

WESTERN CANADA & HAWAII

ARVA DIV. OF RON MERRITT CO.
120 West Thomas Street
Seattle 99, Washington
Murdock 7337

N. & S. CAROLINA — S. VIRGINIA

JAMES L. HIGHSMITH
737 Providence Rd.
Charlotte, North Carolina
Franklin 7-2546

CALIFORNIA, ARIZONA, NEVADA

McCARTHY ASSOCIATES
1055 East Walnut
Pasadena, California
Sycamore 2-8272

934 West Laurel Street
San Diego, California
Belmont 9-4015

NORTHERN CALIFORNIA

441 W. California Avenue
Palo Alto, California
Davenport 5-6136

GEORGIA, KENTUCKY, TENNESSEE, and ALABAMA

BIVINS & CALDWELL
3133 Maple Dr., N.E.
Atlanta 5, Georgia
Cedar 3-7522

FLORIDA

ARTHUR H. LYNCH AND ASSOCIATES
35 W. North Shore Avenue
Fort Myers, Florida
Edison 4-4431

NO. ILLINOIS and SO. WISCONSIN

SAFFRO & GETTLEMAN CO.
5209 No. Kimball Avenue
Chicago 25, Illinois
Juniper 8-0905

INDIANA

LAW INSTRUMENT COMPANY
P. O. Box 95
Angola, Indiana
217 & 8101-R

P.O. Box 6562
Indianapolis 27, Indiana
State 7-0009

KANSAS, WESTERN MISSOURI

HARRIS-HANSON COMPANY
7916 Paseo Avenue
Kansas City 30, Mo.
Hiland 6744

EASTERN MISSOURI, SOUTHERN ILLINOIS

HARRIS-HANSON COMPANY
2814 South Brentwood Blvd.
St. Louis 17, Mo.
Mission 7-4350

MICHIGAN

S. STERLING COMPANY
15310 W. McNichols Road
Detroit 35, Michigan
Broadway 3-2900

OHIO

S. STERLING COMPANY
4311 Mayfield Road
Cleveland 21, Ohio
Evergreen 2-4114

MINNESOTA, IOWA, NEBRASKA N. & S. DAKOTA, NO. WISCONSIN

THE HEIMANN COMPANY
1711 Hawthorne Avenue
Minneapolis 3, Minnesota
Federal 2-5457

NEW MEXICO

GENE FRENCH COMPANY
P.O. Box 8346
Albuquerque, New Mexico
AL 8-0924

PHILADELPHIA, EASTERN PENNA. & SOUTH NEW JERSEY

I. E. ROBINSON (Main Branch)
7404 West Chester Pike
Upper Darby, Penna.
Sherwood 8-1294

2120 Market St.
Camp Hill, Penna.
Regent 7-6791

905 Main St.
Asbury Park, New Jersey
Kellog 1-3150

CENTRAL NEW YORK

J. F. WULFETANGE, JR.
4505 E. Genesee St.
De Witt 14, New York
Gibson 6-3330

WESTERN NEW YORK

ROBERT F. LAMB
1807 Elmwood Avenue
Buffalo 7, New York
Bedford 3757

NEW ENGLAND AND EASTERN N. Y.

YEWELL ASSOCIATES, INC.
Middlesex Turnpike
Burlington, Mass.
Burlington 7-2561

1101 E. Main Street
Bridgeport, Conn.
Forest 6-3456

OREGON AND WASHINGTON WESTERN IDAHO

THE JAMES L. KEARNS COMPANY
6055 N. E. Glisan St.
Portland 13, Oregon
Belmont 6-2444

PITTSBURGH, W. PA. AND W. VA.

H. E. RANSFORD COMPANY
5400 Clairton Blvd.
Pittsburgh 36, Penn.
Tuxedo 4-3425

TEXAS

EARL LIPSCOMB ASSOCIATES
P. O. Box 7084
Dallas, Texas
Fleetwood 7-1881

EASTERN IDAHO

MONTANA

UTAH, COLORADO AND WYOMING

LAHANA AND COMPANY
1886 South Broadway
Denver 10, Colorado
Pearl 3-3791

WASHINGTON, D. C., MD. AND DEL.

HORMAN ASSOCIATES, INC.
2017 "S" Street, N.W.
Washington 9, D. C.
Decatur 2-5705

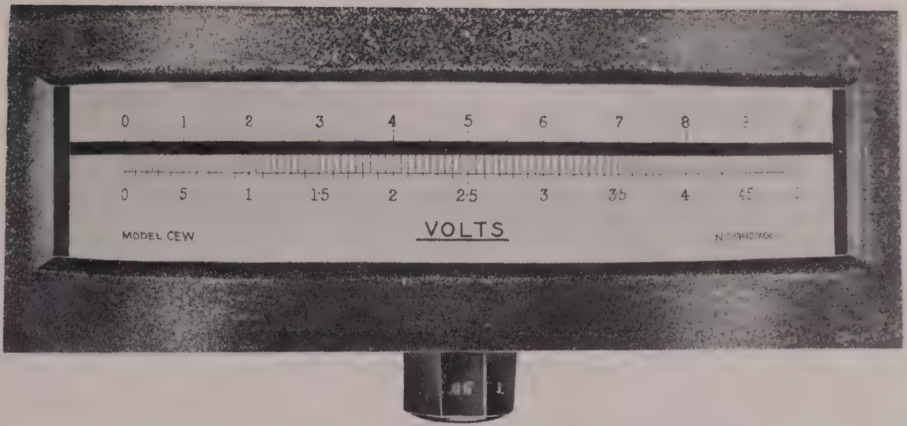
635 St. John's Road
Baltimore 10, Maryland
Hopkins 7-2290

ALTERNATING AND DIRECT CURRENT

REFERENCE STANDARD
PANEL INSTRUMENTS

WITH ACCURACIES TO .25 OF 1%

- MILLIVOLTMETERS
- VOLTMETERS
- KILOVOLTMETERS
- MICROAMMETERS
- MILLIAMMETERS
- AMMETERS
- WATTMETERS
- FLUXMETERS
- FREQUENCY INSTRUMENTS
- RATIOMETERS
- CURRENT PRODUCT INSTRUMENTS
- DIFFERENTIAL GALVANOMETERS
- POLYRANGERS
- MUTUAL CONDUCTANCE INSTRUMENTS
- FLUX VOLTMETERS


0 1 2 3 4 5 6 7 8
0 .5 1 1.5 2 2.5 3 3.5 4 4.5
MODEL CEW
VOLTS

EDGEWISE TYPE EW-7
AC-DC case design with a *long* 7.1″ hand drawn mirrored scale.

MILLIAMPERES
DIRECT CURRENT
MODEL UP
SENSITIVE RESEARCH INSTRUMENT CORPORATION
SENSITIVE RESEARCH

MODEL UPP
Compact D.C. rectangular type with a 4″ hand drawn mirrored scale.

Permanently Precise!

SENSITIVE
RESEARCH
INSTRUMENT
CORPORATION

Symbol of Quality

NEW ROCHELLE, N. Y.

S. STERLING CO.
Manufacturers' Representatives
5827 MAYFIELD ROAD
CLEVELAND 24, OHIO
Hillcrest 2-8080

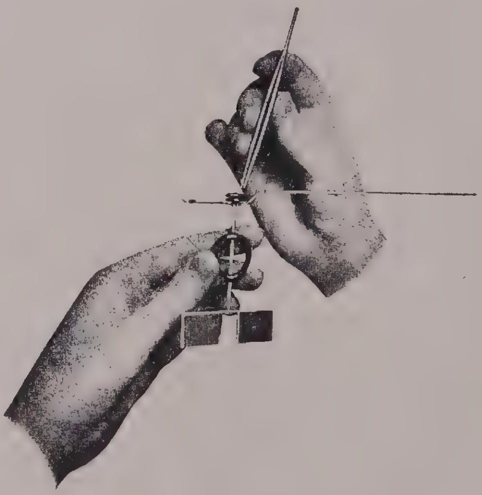
ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

SENSITIVE RESEARCH PANEL INSTRUMENTS

All of the portable reference standard instruments and ultra-sensitive instruments that Sensitive Research Instrument Corporation manufactures for horizontal use may be procured with the same degree of high accuracy and electrical efficiency for panel mounting. They conform to the most rigid specifications normally reserved for secondary electrical indicating standards in the laboratory. This bulletin's main purpose is to present to the design, research, application engineer, or manufacturer of electronic equipment, a compact resume of the wide scope of Sensitive Research's panel instrumentation. For a complete listing of exact ranges and prices, and a broader discussion of models listed in this bulletin, please consult our new Catalog No. 70, now available. We have cross referenced this brochure with Catalog No. 70 for your convenience.

SENSITIVE RESEARCH manufactures both vertically mounted and edgewise panel instruments. Each has its own particular advantage. The vertically mounted is rugged, easy to read, conveniently mounted, and economical in price. The edgewise panel type is higher in price but can be made in ultra-high sensitivities and accuracies of .25 of 1%. *It incorporates ruggedness, excellent readability, and distinction of design.* Both types are offered with special scales to fit your application. You can rest assured if you specify Sensitive Research, you will not only receive the best in panel instrumentation but also the benefit of our desire to assist you in doing the best job possible.

GENERAL SPECIFICATIONS



1. Individually calibrated hand drawn scale.
2. Anti-parallax mirror.
3. Magnetic Shielding.
4. Electrostatic Shielding.
5. Temperature compensation.
6. Warp-proof scale plate.
7. Knife edge pointer. (Lance type if specified).
8. Self contained. (Unless otherwise noted).
9. Large, stable moving coil assemblies. (All Sensitive Research Instrument Corporation panel instruments contain the same moving coil and permanent magnet assemblies that exist in our .1 of 1% accurate Laboratory Standards. No concession is made in size or quality of components. This differs greatly from the design of the usual panel instrument with its small coil and permanent magnet, where low cost production is of first importance and dictates component quality.)

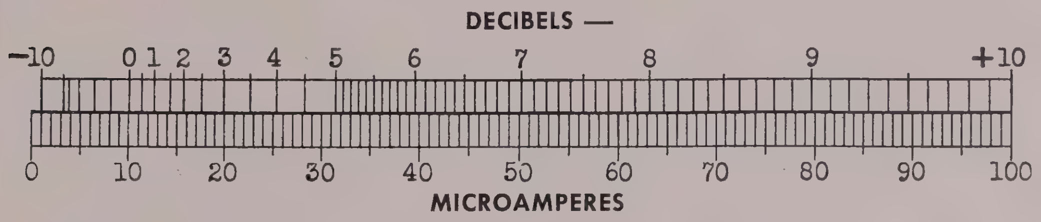
ADDITIONAL SPECIFICATIONS

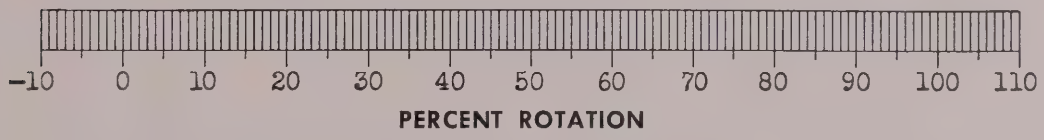
1. DIAMOND PIVOTS and "calibrated spring" shock mounted sapphire jewels are standard in all high sensitivity instruments and are included in the price. This unique assembly will withstand the tremendous shock of a three foot drop onto a concrete floor without damage to either component. This means a virtually "friction free" moving element in the most ultra-sensitive microammeter, millivoltmeter, or thermocouple instrument. The average ruggedized panel instrument has a steel pivot with a riding surface of .015 inches. Diamond pivots can be ground to a riding surface of .0008 inches. This means a friction coefficient of better than 18 to 1 in favor of diamond pivots. Diamond pivots are completely non-magnetic and hence free from any hysteresis effects in an instrument. While they are standard equipment in high sensitivity instruments, they are offered as an accessory item in *all* other instruments at $30.00 per assembly. (See page 7 of this bulletin)

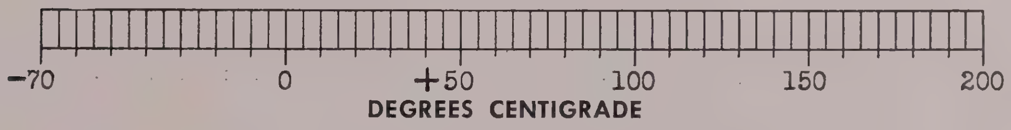
2. SPECIAL SCALES are available to fit your application. Illustrated below are samples of hand drawn, individually calibrated scales with special markings. Such scales can be made to your specifications with your company's name and any designation desired.

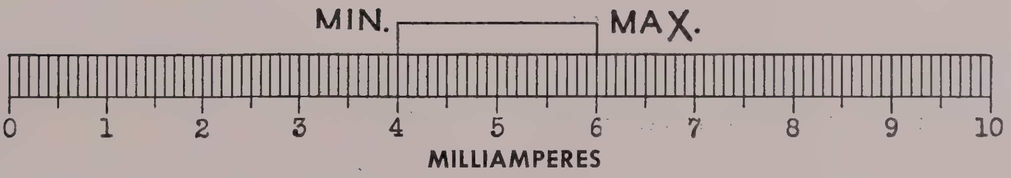
TYPICAL FULL SIZE FACSIMILE SPECIAL SCALES

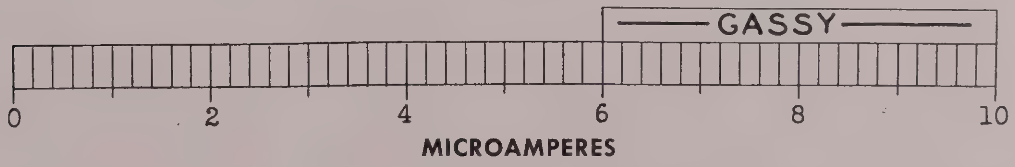
With hand drawn Black Lines on White Background — Colored Lines if desired.


DECIBELS —
−10
0 1 2 3 4 5 6 7 8 9
+10
0 10 20 30 40 50 60 70 80 90 100
MICROAMPERES


−10 0 10 20 30 40 50 60 70 80 90 100 110
PERCENT ROTATION


−70 0 +50 100 150 200
DEGREES CENTIGRADE


MIN.
MAX.
0 1 2 3 4 5 6 7 8 9 10
MILLIAMPERES


GASSY
0 2 4 6 8 10
MICROAMPERES

3. WATER-PROOFING AND RUGGEDIZATION

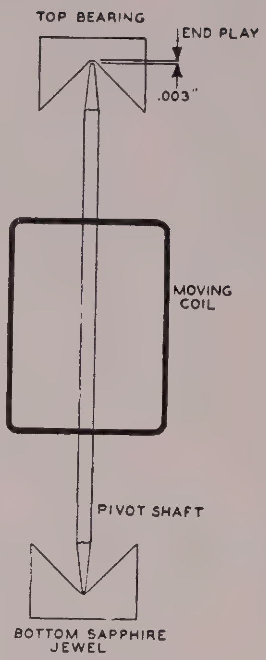
Special correspondence is invited where your application calls for an accurate electrical indicating panel instrument to withstand severe handling and abnormal environmental conditions.

WHY EDGEWISE PANEL INSTRUMENTS ?

The vertical, flat faced panel instrument with horizontal pivots is limited in its accuracy and sensitivity. Its greatest advantages are its mounting convenience, and relatively low cost. Yet, an indicating instrument with limited accuracy and sensitivity leaves much to be desired in many applications.

Many times we have been asked, "Why these limitations on vertical flat faced panel instruments?"

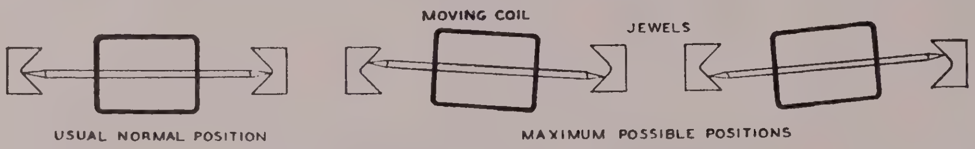
The reason is as shown in the accompanying illustrations.



VERTICAL PIVOT

A bench type or portable precision instrument usually uses vertically disposed pivots. The entire weight of the moving coil is carried by the bottom pivot which is in constant contact with its sapphire jewel. A slight amount of end play in the top jewel will NOT materially change the position of the moving coil in the magnetic field. Such a design properly assembled will allow calibration accuracies to better than .05%. The very point of the pivot on the sapphire jewel will only be a few millionths of a square inch.

Now let us look at the usual panel instrument with horizontal pivots.

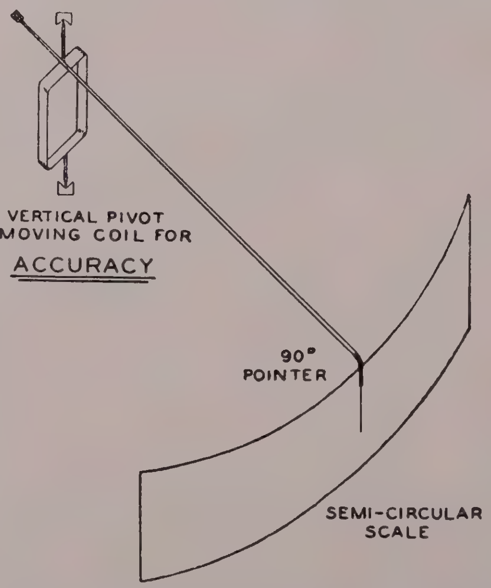


HORIZONTAL PIVOT

Note that we now have end play at both pivots and that the moving coil can assume a variety of different positions in the magnetic field. Note also that the pivot bearing surfaces have more than DOUBLED over that of the vertical pivot design.

It can be seen from this discussion that an extremely high torque-weight ratio is necessary for good accuracy and repeatability in an instrument whose pivots ride horizontally. It follows that an extremely high torgue-weight ratio means strong instrument springs, and to design an instrument with strong springs, sacrifices in sensitivity must be made. If the sensitivity is increased then the spring strength must be reduced and repeatability and accuracy is impaired due to pivot roll and bearing friction. It is interesting to note on a comparison basis that the same accuracy of indication can be maintained in an ultra-sensitive edgewise panel instrument as in a low sensitivity vertical panel type, even though the edgewise model may have a range sensitivity that is 20,000 per cent higher, and a spring strength that is lower by a factor of 30.

With these explanations in mind, we present our high sensitivity ACCURATE edgewise panel instruments. They have vertical pivots with no zero uncertainty or undue pivot friction. Sensitive Research panel models are true reference standard electrical indicating instruments.



BASIC ASSEMBLY EDGEWISE INSTRUMENT

MODEL DESIGNATIONS OF EDGEWISE PANEL INSTRUMENTS

Instruments that are available for edgewise panel mounting have their nomenclature based on the original portable models as listed in Catalog No. 70, plus the suffix EW-5 or EW-7. The EW-5 designates an edgewise panel type with a 5" scale length, and the EW-7, an edgewise panel type with a 7" scale length. In addition, there is both a shallow and deep EW-5 and EW-7 type. The furnishing of either a deep or shallow case is specific to the instrument model and is indicated in both this bulletin and Catalog No. 70. In most cases either the EW-5 or EW-7 type is available for panel mounting any model, but there are some instances where because of high sensitivity only the EW-5 case is offered.

As an example of model designation let us assume you have selected from our catalog a dynamometer instrument for your application. Catalog No. 70 would list this as our Model D. If you desired to panel mount this Model D, you would specify the Model DEW-5 or DEW-7 depending on the scale length of your choice. The code word for the ranges you selected would remain the same.

Where not specifically listed in a separate pricing schedule there is an additional charge for edgewise panel mounting in an EW case. For correct price information this charge should be added to the cost of the portable model as listed in Catalog No. 70.

Type	Additional Price
Shallow EW-5	**$20.00**
Shallow EW-7	**25.00**
Deep EW-5	**25.00**
Deep EW-7	**30.00**
PDW-EW-5 (Polyphase Wattmeter Case)	**50.00**

IMPORTANT — The Model JW-4 listed in this bulletin is a separate edgewise panel model by itself. While it closely resembles the sensitivities, accuracies, and ranges listed in our Catalog No. 70, for the Models J and University D'Arsonval, it has no exact relation to them. There is no adaptation of this case design available for any other models, and prices listed for it include the edgewise panel case.

We regret that the University Model in the dynamometer, thermocouple D'Arsonval, and electrostatic types, is not available for edgewise panel mounting. These designs are offerd for panel mounting only in the Models D, A, and ESD.

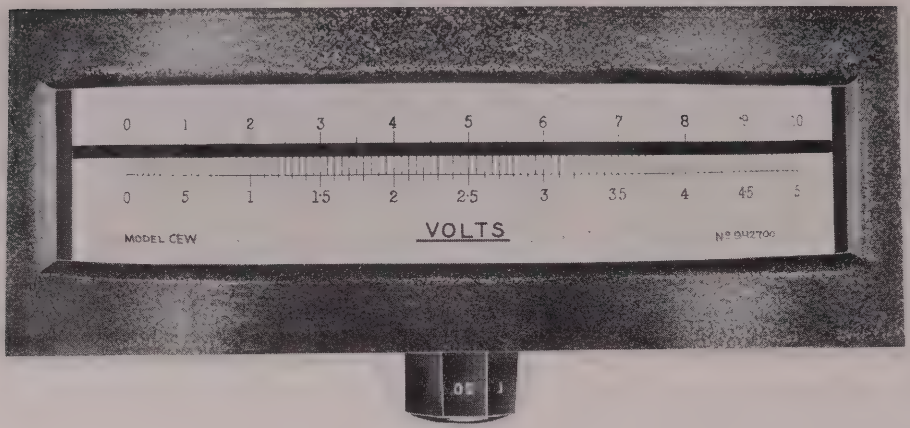
NOTE: In the general listing of instrument models that follow, the range of full scale sensitivities given merely denote the maximum and minimum sensitivities for that particular type. Except in the case of POLYRANGER models where the actual instrument ranges are given, it does not necessarily follow that the entire sensitivity spread can be incorporated in a single unit. For sensitivities that can be combined in a single instrument see the descriptive pages referenced in Catalog No. 70.

EW AND JW CASE CONSTRUCTION AND MOUNTING DIMENSIONS

The EW and JW type case is made of cast aluminum and is normally furnished in a black wrinkle finish. Mounting dimensions are listed on page 15 of this bulletin.

DIRECT CURRENT EDGEWISE PANEL INSTRUMENTS

Model CEW-5 5″ Scale Length
Model CEW-7 7″ Scale Length



Measures——D.C. microamperes, milliamperes, amperes, millivolts and volts.

Accuracy——.25 of 1%.

Type————Double pivoted D'Arsonval.

Period————1 second.

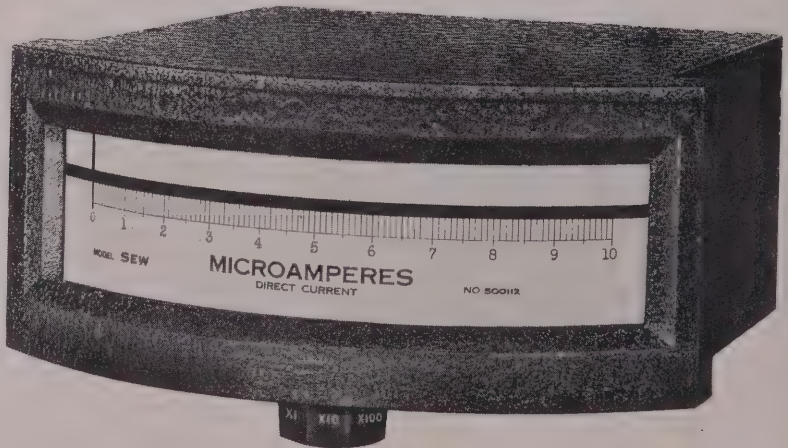
Availability—As a single or multirange instrument with up to 8 ranges internally switch controlled.

Sensitivity——From 30 microamperes to 50 amperes, and 50 millivolts to 1500 volts full scale. Higher ranges available by the use of external shunts and multipliers.(See pages 209-210 Catalog No. 70). Voltmeters are either 1000 ohms per volt or 5000 ohms per volt.

Prices————Range from $180 to $328.

For a broader discussion of the Model C see pages 80 to 82 Catalog No. 70.

Model SEW-5 5″ Scale Length
Model SEW-7 7″ Scale Length



Measures——D.C. microamperes, milliamperes, millivolts and volts.

Accuracy——.5 of 1%. (1% below 5 microamperes).

Type————Double pivoted D'Arsonval.

Period————2 to 3 seconds.

Availability—As a single or multirange instrument with up to 8 ranges internally switch controlled.

Sensitivity——Ultra-high sensitivities from 1 microampere to 1000 milliamperes and 1 millivolt to 1500 volts. Higher ranges may be obtained by the use of external multipliers and shunts. (See Pages 209-110 Catalog No. 70). Low and medium resistance current designs offered. Diamond Pivots included in price of all ultra-high sensitivity designs. No magnetic shielding on instruments with ranges of 5 microamperes or less. EW-5 case only on all high sensitivity types. Voltmeters up to 1,000,000 ohms per volt.

Prices————Range from $175 to $400.

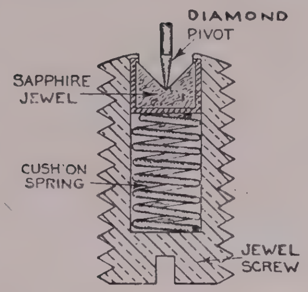
For a broader discussion of the Model S see pages 73 to 78 Catalog No. 70.

DIRECT CURRENT EDGEWISE PANEL INSTRUMENTS

Model HSEW-5 5″ Scale Length

Measures: D.C. millivolts and volts.

High resistance, ultra sensitive, multi-range millivoltmeter-voltmeters with the same general specifications as the Model SEW-5. Sensitivities to 1,000,000 ohms per volt. Furnished with diamond pivots only.



(See Pages 79 or 149 or 203 of Catalog No. 70 for exact ranges and pricing.

Model FMEW-5 5″ Scale Length
FSEW-5
Model FMEW-7 7″ Scale Length
FSEW-7

(with standard 10 turn search coil)

Measures——Flux density.

Accuracy——.5 of 1%.

Type————Double pivoted fluxmeter (ballistic galvanometer).

Availability—Furnished as zero center instruments. Toggle switch for zeroing, and mercury batteries furnished as separate items for mounting by purchaser in his panel.

Sensitivity——Model FMEW has 5 ranges from 10,000 lines per division to 1,000,000 lines per division using a single turn search coil. Model FSEW is a single range instrument within limits of these sensitivities. Sensitivity increased with use of a multiturn search coil.

FMEW-5	$305	FMEW-7	$310	FSEW-7	$220	FSEW-5	$215

Standard 10 turn search coil	$40.00
Standard magnet and search coil for calibration purposes	$85

For a broader discussion of fluxmeters and magnetic measuring instruments see Pages 169 to 182 Catalog No. 70.

Model SDEW-5 5″ Scale Length
SDEW-7 7″ Scale Length

Measures——Addition or subtraction of two D.C. currents or voltages.

Accuracy——.5 of 1%. (1% below 5 microamperes).

Type————Double pivoted D'Arsonval. 2 coils wound on the same coil form that will subtract or add depending on how polarity of each coil is connected. (Differential Galvanometer).

Period————1 to 3 seconds.

Availability—As a single or switch controlled dual range instrument. Center zero type. Each coil will withstand continuous overloads of 1000% and large additional momentary overloads. Coils are insulated from each other for a difference of potential of 300 volts.

Sensitivity——From 2 microamperes and 1.5 millivolts to 500 milliamperes and 1 volt full scale. Higher ranges on request. Ultra-high sensitivities in EW-5 case only.

Prices————Range from $243 to $318.

*FOR DIRECT CURRENT INSTRUMENTS WITH AN ACCURACY OF .05 OF 1% AND A SCALE SUPPRESSION OF 90%, WRITE FOR INFORMATION ON THE NEW SENSITIVE RESEARCH **"DIFFERENTIAL 63 INCREMETER."***

DIRECT CURRENT EDGEWISE PANEL INSTRUMENTS

Model JDJW-4 4″ Scale Length

Differential galvanometer with characteristics similar to Model SDEW-5. Sensitivity is not quite as high, but full scale ranges offered are identical. Prices range from $183.00 to $206.00.

For a broader discussion of the Model JDJW-4 see page 192, Catalog No. 70.

Model RAEW-5 5″ Scale Length
RAEW-7 7″ Scale Length

Measures—The ratio of two D.C. currents or voltages.

Accuracy—.25 of 1% maximum at unity ratio. 1% minimum near zero or infinity.

Type—Double pivoted D'Arsonval with 2 crossed coils having no restoring torgue. Will divide input of one coil into the other. (Ratiometer).

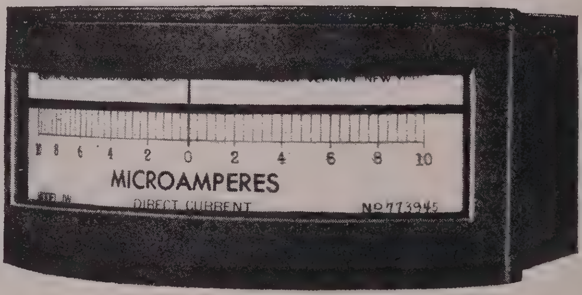
Availability—As a switch controlled current instrument. Voltage ranges are obtained by adding series resistance to appropriate current sensitivities.

Sensitivity—From 50 microamperes to 50 milliamperes.

Prices—Range from $315 to $320.

For a broader discussion of Ratiometers see pages 194-195 Catalog No. 70.

Model JW-4 4″ Scale Length



Measures—D.C. microamperes, milliamperes, millivolts and volts.

Accuracy—.5 of 1%. (1% below ranges of 5 microamperes).

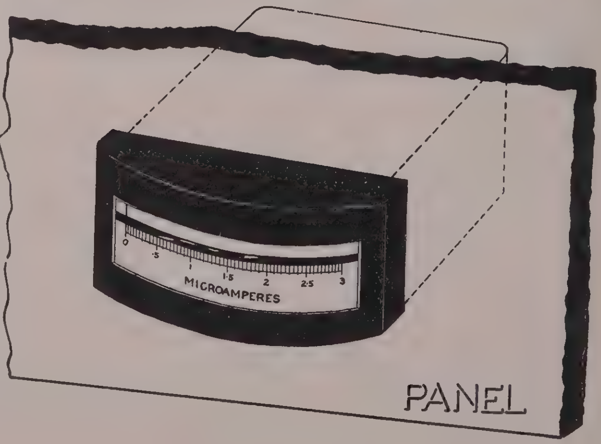
Type—Double pivoted D'Arsonval.

Period—1 to 3 seconds.

Availability—As a single, double or triple range instrument. Terminals on rear of case only. Space does not permit switch installation internally. Not magnetically shielded below 5 microamperes.

Sensitivity—From 2 microamperes and 1.5 millivolts, to 1 ampere and 750 volts. Higher ranges may be obtained by using external multipliers and shunts. (See Pages 209-210 Catalog No. 70).

Prices—Range from $105 to $150.



For a broader discussion of the Model JW-4 see pages 88 to 89 Catalog No. 70.

ALTERNATING AND DIRECT CURRENT
EDGEWISE PANEL INSTRUMENTS

Model DEW-5 5″ Scale Length
DEW-7 7″ Scale Length

Measures——A.C. and D.C. milliamperes, amperes and volts. Reads true RMS.

Accuracy——.25 of 1%.

Type————Double pivoted electrodynamometer.

Period———Approx. 3 seconds.

Frequency——Between D.C. and 15 cps. to 2500 cps. with certain range limitations. (See Page 107 Catalog No. 70).

Availability—As a single or multirange instrument. Voltmeter may be switch controlled. Where instruments draw appreciable power they have an external multiplier or shunt box attached to rear of case.

Sensitivity——From 1.5 volts and 5 milliamperes to 1000 volts and 20 amperes full scale. Ohms per volt listings for voltmeters and resistance listings for current meters in Catalog No. 70 are for 60 cps. only. Frequency compensated instruments have a lower ohms per volt.

Prices————Range from $230 to $375.

For a broader discussion of dynamometer instruments, see pages 106-108, Catalog No. 70.

Model DYSPEW-5 5″ Scale Length
DYSPEW-7 7″ Scale Length

Measures——The product of two current or voltages. Reads true R.M.S.

Accuracy——.25 of 1%.

Type————Double pivoted electrodynamometer. Multiplies two input currents or voltages. (Current Product Meter).

Period———Approx. 3 seconds.

Frequency——D.C. and 25-500 cps.

Availability—Single or dual range instrument with binding posts on rear of case.

Sensitivity——From .001 to .5 amperes ^{2}.

Prices————Range from $305 to $340.

For a broader discussion of current product instruments see page 196 Catalog No. 70.

* Model DWEW-5 5″ Scale Length
* Model DWEW-7 7″ Scale Length
†Model DLWEW-5 5″ Scale Length

Measures——DC and AC watts down to * 50% P.F. and down to † 20% P.F. Reads true R.M.S.

Accuracy——*.25 of 1% and †.5 of 1%.

Type————Double pivoted electrodynamometer. (Single phase wattmeter).

Period———Approx. 3 seconds.

Frequency——*D.C. and 25-800 cps. †D.C. and A.C. 25 to 500 cps.

Availability—3 or 4 watt ranges, 2 or 3 volt ranges, and 2 current ranges are standard. If less or more ranges are desired correspondence is suggested.

Sensitivity——From .05 watts to 3000 watts full scale depending on P.F. and accuracy desired. Approximately 100 to 333 ohms per volt potential circuit loading, except in very special cases.

Prices————Range from $290 to $440.

For a broader discussion of single phase wattmeters see pages 113 to 119 Catalog No. 70.

ALTERNATING AND DIRECT CURRENT
EDGEWISE PANEL INSTRUMENTS

* Model PDWEW-5 5″ Scale Length
† Model PDLWEW-5 5″ Scale Length

Measures——DC and AC watts down to * 50% P.F. and down to † 20% P.F. Reads true RMS.

Accuracy——*.5 of 1% and †.75 of 1%.

Type————Double pivoted electrodynamometer. Two moving coils on a single shaft for three phase power measurements (Polyphase Wattmeter).

Frequency——*D.C. and A.C. from 25 to 800 cycles.
†D.C. and A.C. 25 to 500 cps.

Availability—3 or 4 watt ranges, 2 or 3 volt ranges, and 2 current ranges. If less or more ranges are desired correspondence is suggested.

Sensitivity——From 15 watts to 2000 watts full scale depending on power factor and accuracy desired. Approximately 100 to 333 ohms per volt potential circuit loading.

Prices————Range from $600 to $635.

For a broader discussion of polyphase wattmeters see pages 126 to 132 Catalog No. 70.

Model AEW-5 5″ Scale Length
Model AEW-7 7″ Scale Length

Measures——AC-DC milliamperes, amperes, millivolts, volts. Reads true R.M.S.

Accuracy——.75 of 1%. (.5 of 1% on special order).

Type————Double pivoted thermocouple D'Arsonval.

Period————6 seconds (somewhat longer in special cases).

Frequency——DC and 7 cps. to RF. (Varies with Instrument Ranges.)

Availability—As a single or multirange instrument with up to 8 ranges switch controlled. Voltage instruments may have their ranges extended by use of external multipliers. (See page 210 Catalog No. 70).

Sensitivity——From 200 millivolts and 1 millampere, to 1500 volts and 1.5 amperes full scale. Voltmeters are either 100 or 500 ohms per volt.

Prices————Range from $245 to $407.

For a broader discussion of thermocouple instruments see pages 159 to 168 Catalog No. 70. Special correspondence is necessary for instruments to be used below 7 cps.

Model AUEW-5 Audio frequency milliammeter & voltmeter
Model RFEW-5 Radio frequency milliammeter & voltmeter
Model XTEW-5 Radio frequency ammeter

The above instruments are similar in characteristics to the Model AEW 5 & 7 differing only in usable frequency range.

We regret that due to space limitations, thermocouple instruments are NOT available in the edgewise panel design with the "safety key" unless mounted on a standard rack size panel. If this feature IS necessary, instruments can be supplied for standard 19″ relay rack mounting. Add $50.00 to the price of the instrument plus $40.00 for the safety key feature. Panels can be ⅛″ gray aluminum or 5/16″ black bakelite, as desired. The thermocouple replacement feature (TRF) is available on these instruments without rack mounting. Add $30.00 to the cost of the instrument.

ALTERNATING AND DIRECT CURRENT

EDGEWISE PANEL INSTRUMENTS

Model ESDEW-5 5″ Scale Length (Single Range Only)

Model ESDEW-7 5″ Scale Length (Multirange)

Measures——AC-DC volts and kilovolts. Reads true R.M.S. Available with Model VPA peak voltage adaptor for peak or surge crest volt readings.

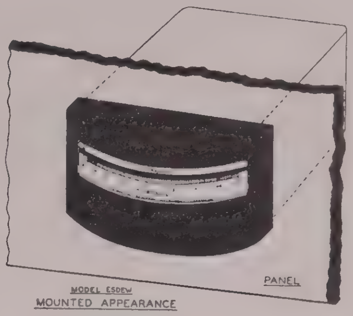
Accuracy——1%.

Type————Double pivoted electrostatic.

Period————5 to 10 seconds depending on voltage range.

Frequency——DC and AC up to 300,000 cycles depending on voltage range.

Availability—Single and multirange instruments with binding posts on rear. Lowest range is for AC-DC use. Additional ranges are obtained by capacitor multipliers and are limited to AC measurements only.



Sensitivity——From 120 volts to 6000 volts full scale. Input resistance 10^{14} ohms. Internal capacitance varies according to range sensitivity from approximately 220 MMFD on 120 volt range to 22 MMFD on 60 KV range.

Prices————Range from $200 to $390.

For a broader discussion of the Model ESD see pages 137 to 147 Catalog No. 70.

NOTE: Higher volt ranges may be obtained in our electrostatic voltmeter Model ESH fitted with brackets for panel mounting. (Add $30 to price).

Sensitivities in single and multirange instruments from 5000 volts to 100,000 volts. Accuracy and electrical characteristics similar to Model ESDEW, except multirange instruments are designed so that all ranges are usable on AC and DC.

For a broader discussion of the Model ESH, see pages 144 & 145, Catalog No. 70.

Model GMEW-5 5″ Scale Length

Measures——Mutual conductance of vacuum tubes in micromhos.

Accuracy——.5 of 1%.

Type————Double pivoted electrodynamometer.

Period————3 to 5 seconds depending on ranges selected.

Frequency——50-60 cps.

Availability—As a multirange instrument with full scale ranges in micromhos switch controlled if desired. Input check switch furnished separately for mounting in panel by purchaser.

Sensitivity——From 20 micromhos to 100,000 micromhos. Special low grid signal and high speed medium signal design available. Input check currents of 160 milliamperes or 80 milliamperes.

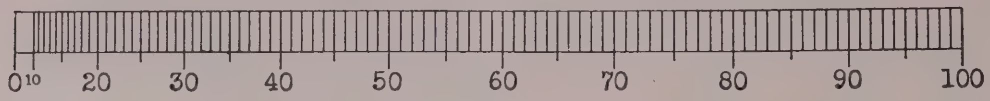
Prices————Ranges from $280 to $340.

For a broader discussion of GM instruments see pages 185 to 188 Catalog No. 70.

The Model GMRP for measurements of mutual conductance and plate impedance can be made for rack panel mounting only. Correspondence necessary. For discussion of GMRP instruments see page 188 Catalog No. 70.

ALTERNATING CURRENT EDGEWISE PANEL INSTRUMENTS

Model MIEW-5 5″ Scale Length
MIEW-7 7″ Scale Length



FACSIMILE SCALE

Measures—AC milliamperes, amperes and volts. Reads true R.M.S.

Accuracy—.5 of 1%.

Type—Double pivoted moving vane (soft iron).

Period—3 seconds.

Frequency—25 to 1000 cps. For frequency limitations see page 111 Catalog No. 70.

Availability—Single and multirange instruments with terminals on the rear only. Voltmeters above 150 volts are supplied with external multipliers for panel mounting.

Sensitivity—From 5 volts and 10 milliamperes to 750 volts and 20 amperes.

Prices—Range from $135 to $179.

For a broader discussion of Moving Iron Instruments see pages 111 to 112 Catalog No. 70.

Model FLVEW-5 5″ Scale Length
FLVEW-7 7″ Scale Length

Measures—AC volts. Reads average values. Used primarily as flux voltmeters for magnetic measurements.

Accuracy—.5 of 1% (.25 of 1% above 30 volts on special order).

Type—Double pivoted D'Arsonval with full wave rectifier. (Flux voltmeter).

Period—3 seconds.

Frequency—50-1000 cps.

Availability—As a single or switch controlled multirange instrument.

Sensitivity—From 5 volts to 750 volts full scale. Either 1000 ohms per volt or 3333 ohms per volt.

Prices—Range from $220 to $365.

For a broader discussion of flux voltmeters see page 182 Catalog No. 70.

For technical information on the use of the flux voltmeter for magnetic measurements see pages 180 to 181 Catalog No. 70.

Model FREEW-5 5″ Scale Length
FREEW-7 7″ Scale Length

Measures—Low audio frequency over a narrow range spread or from zero up to a specific frequency.

Accuracy—.25 of 1% of center frequency or full scale value.

Type—Double pivoted D'Arsonval. (Frequency meter).

Period—3 seconds.

Availability—Single frequency ranges with single or switch controlled multirange voltage levels. Independent of applied voltage up to ± 15% of voltage range. Suppressed scale to read within a narrow frequency spread or to read from zero to a specific full scale frequency.

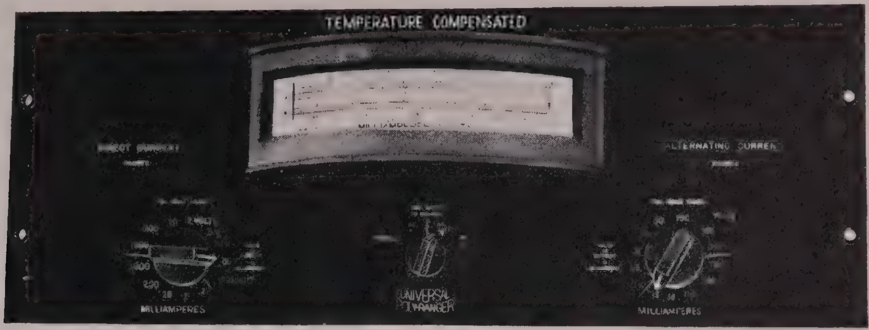
Sensitivity—Ranges available as per following examples: 58-64 cps. or 375-425 cps. or 0-1000 cps.

Prices—Range from $345 to $450.

For a broader discussion of Frequency Instruments see pages 205 to 208 Catalog No. 70.

DC, AC, AND AC-DC POLYRANGERS FOR RACK PANEL MOUNTING

SENSITIVE RESEARCH Instrument Corporation offers a wide variety of POLYRANGERS with overlapping switch controlled current and voltage ranges. These polyrangers have their basic moving elements in an EW-5 or EW-7 case design (as listed below), which is installed in a standard 19″ x 7″ x 5/16″ black bakelite panel. The panel contains the range switches, input binding posts, engraving and internal circuitry necessary to the operation of the instrument. General specifications and models listed below.



Model	Ranges Full Scale	Scale Length	Accuracy	Price
USPEW-5	200 ua/2/20/200/1000 ma/ 2 amp D.C. 5/50/100/500 mv/2/20/200/1000 v D.C. 15/30/150/300/1500 ma/3 amp A.C.-D.C. .3/1.5/3/15/30/150/300/750 v A.C.-D.C.	5″	A.C.-D.C. .75 of 1% D.C. .5 of 1%	$485.
U88EW-5	.2/.3/.5/.75/1/1.5/2/3/5/7.5/10/15/20/30/50/75/100/150/200/300/500/750/1000/1500 ma D.C. .02/.03/.05/.075/.1/.15/.2/.3/.5/.75/1/1.5/2/3/5/7.5/10/15/20/30/50/75/100/150/200/300/500/750 v D.C. 10/15/20/30/50/75/100/150/200/300/500/750/1000/1500/2000/3000 ma A.C.-D.C. .5/.75/1/1.5/2/3/5/7.5/10/15/20/30/50/75/100/150/200/300/500/750 v A.C.-D.C.	5″	A.C.-D.C. .75 of 1% D.C. .5 of 1%	$625.
WVAEW-7	1/1.5/3/7.5/15/30/75/150/300/750 ma/1.5/3/7.5/15 amp. D.C. 100/150/300/750 mv/1.5/3/7.5/15/30/75/150/300/1000 volts D.C.	7″	D.C. .25 of 1%	$470.
3-CEW-7	1.5/3/7.5/30/150/300/750 ma/3 amp D.C. 3/15/30/150/300/750 v D.C.	7″	D.C. .25 of 1%	$370.
4-CEW-7	10/50/100/500 ma/1/5/10 amp D.C. 1/5/10/50/100/500/1000 v D.C.	7″	D.C. .25 of 1%	$370.
1-SEW-5	100 ua/1/10/100/1000 ma D.C. 5/10/50/100 mv/1/10/100/1000 v D.C.	5″	D.C. .5 of 1%	1000 ohms v $380. 10,000 ohms $463.
2-SEW-5	200 ua 2/20/200/2000 ma D.C. 5/10/20/100 mv/.2/2/20/200 v D.C.	5″	D.C. .5 of 1%	$380.
1-DYPEW-7	10/30/100/300 ma/1/3/10 amp A.C. 10/30/100/300/1000 v A.C.	7″	A.C. .3 of 1%	$490.
2-DYPEW-7	5/10/20/50/100/200/500 ma/1/2/5/10 amp A.C. 5/10/20/50/100/200/500/1000/* 2000 v A.C.	7″	A.C. .3 of 1%	$575. (* $85. extra for 2000 v range)
1-AA-EW-5	10/50/100/500 ma/1 amp D.C. & A. C. .5/1/5/10/50/100/500 v D.C. & A.C.	5″	D.C. & A.C. .75 of 1%	$379.
1-AB-EW-5	10/50/100/500 ma/1/5 amp D.C. & A. C. .5/1/5/10/50/100/500 v D.C. & A.C.	5″	D.C. & A.C. .75 of 1%	$410.
1-AC-EW-5	10/50/100/500 ma/1 amp D.C. & A.C. .5/1/5/10/50/100/500/1000 v D.C. & A.C.	5″	D.C. & A.C. .75 of 1%	$410.
1-AD-EW-5	10/50/100/500 ma/1/ 5 amp D.C. & A.C. .5/1/5/10/50/100/500/1000 v D.C. & A.C.	5″	D.C. & A.C. .75 of 1%	$440.
2-AEW-5	2/10/50/200/500/1000 ma D.C. & A.C. 2/10/50/200/500 v D.C. & A.C.	5″	D.C. & A.C. .75 of 1%	$410.
3-AEW-5	15/50/150/500 ma/1.5/5 amp D.C. & A.C. .5/1.5/5/15/50/150/500/1500 v D.C. & A.C.	5″	D.C. & A.C. .75 of 1%	$440.
UVAJW-4	1/10/100 ma/1/10 amp D.C. 50/100 mv/1/10/100/1000 v D.C. 10/50/100/500 ma/1/5/10 amp A.C. 10/50/150/500/v A.C.	4″	D.C. .5 of 1% A.C. .75 of 1%	$310.

FOR COMPLETE DESCRIPTIONS OF THE ABOVE INSTRUMENTS, SEE PAGES 33 THROUGH 55 OF OUR COMPLETE CATALOG, NO. 70.

DIRECT CURRENT RECTANGULAR PANEL INSTRUMENTS FOR VERTICAL MOUNTING

Model UPP 4″ Scale Length

The model UPP is a highly accurate, fast acting, rugged vertical panel mounting instrument. It has an exceptionally high torque/weight ratio, and consequently, a split second period. The Model UPP has no pivot roll. Damping is almost critical, allowing for instantaneous readings. This instrument is truly an innovation in the field of panel instruments.

MILLIAMPERES
DIRECT CURRENT
MODEL UP
SENSITIVE RESEARCH INSTRUMENT CORPORATION
SENSITIVE RESEARCH

MODEL UPP
Compact D.C. rectangular type with a 4″ hand drawn mirrored scale.

Measures——DC microamperes, milliamperes, amperes, millivolts, volts.

Accuracy——.5 of 1%.

Type————Double pivoted D'Arsonval.

Period————1 second.

Availability—As a single or multirange instrument with up to 5 ranges, switch controlled.

Sensitivity——From 200 microamperes and 50 millivolts to 1500 milliamperes and 1000 volts full scale. Higher ranges may be obtained by the use of external shunts and multipliers. (See pages 209-210 Catalog No. 70.) Voltmeters can be 1000 ohms per volt on ranges of 1.5 volts or more and 5000 ohms per volt on ranges of 7.5 volts or more.

Prices————Range from $98 to $178.

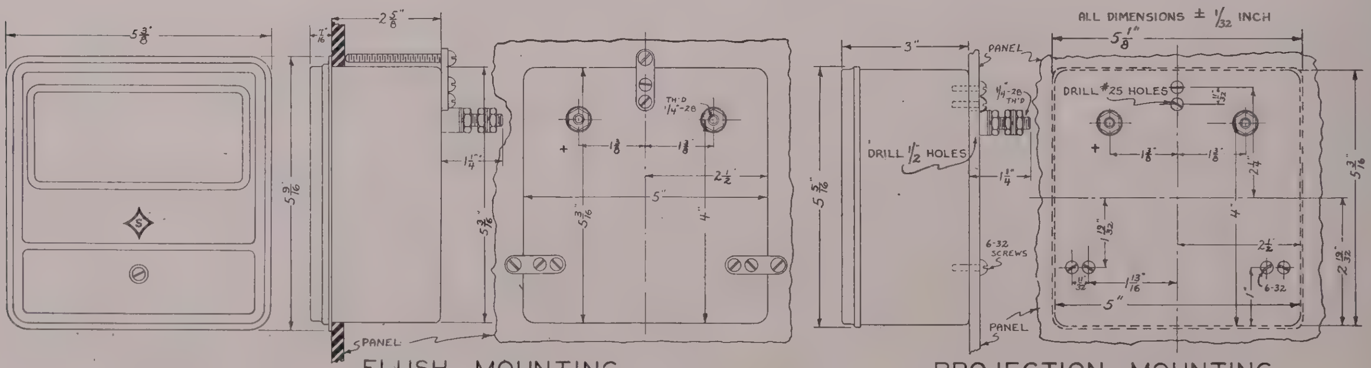
Mounting dimensions for Model UPP same as for Model UP shown below.

Model UP 4″ Scale Length

The Model UP is in all ways similar to the Model UPP except it is limited to microammeters, whose first range is below 200 microamperes. Lowest range offered is 30 microamperes full scale. Accuracy of the Model UP is 1%.

For a broader discussion of the Model UP and Model UPP see pages 95 to 101 Catalog No. 70.

MODELS UP & UPP


5 3/8″
2 5/8″
7/16″
5 9/16
1 1/4″
TH'D 1/4″-28
1 1/8″
2 1/2″
5″
5 3/16
4″
+
PANEL
ALL DIMENSIONS ± 1/32 INCH
3″
5 1/8″
DRILL #25 HOLES
1/4″-28 TH'D
DRILL 1/2 HOLES
2 1/4″
6-32 SCREWS
13/32
2 1/2″
13/16
6-32
5 3/16
2 13/32

FLUSH MOUNTING

PROJECTION MOUNTING

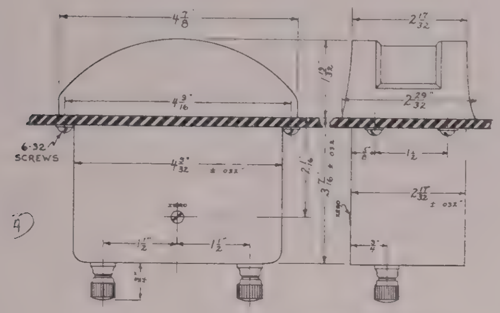
MULTIRANGE INSTRUMENTS CAN BE SUPPLIED WITH STRIP TERMINALS, BINDING POSTS OR SELECTOR SWITCH AT NO EXTRA CHARGE.

MOUNTING DIMENSIONS

For "Sensitive Research" Edgewise Panel Cases

Practically all D.C. and Thermal instruments can be internally switch controlled up to 8 ranges. The switch has 8 positions.

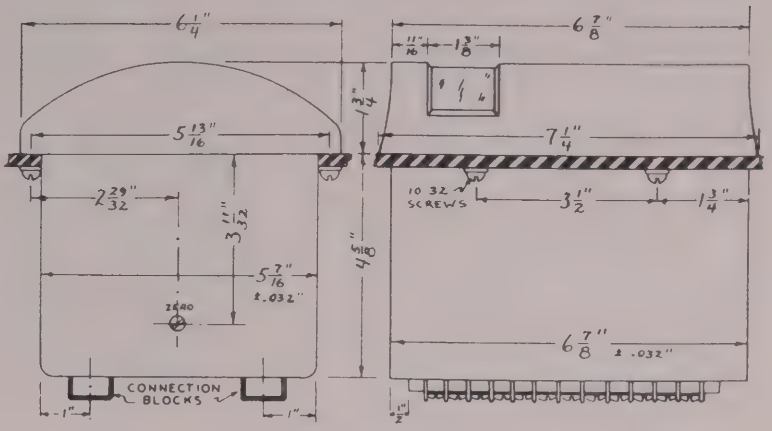
4



4 7/8"
2 17/32"
1 13/32
4 9/16"
2 29/32"
6-32 SCREWS
4 9/32" ± .032"
2 1/16
3 7/16 ± .032
5/8
1 1/2
2 11/32" ± .032"
ZERO
1 1/2"
1 1/2"
3/4"

JW4 PANEL CASE

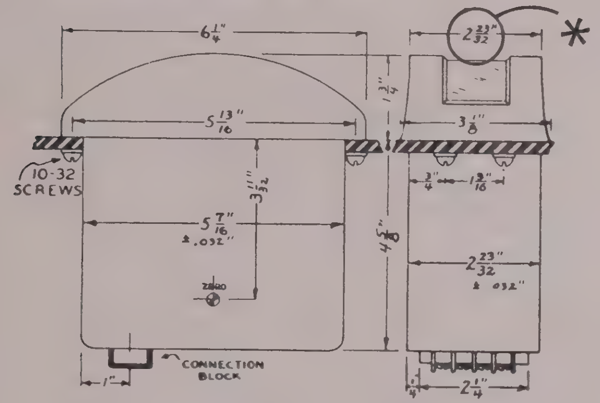
FOR MODELS JW, JDJW, JWV, JWG



6 1/4"
6 7/8"
11/16"
1 3/8"
1 3/4"
5 13/16"
7 1/4"
10 32 SCREWS
3 1/2"
1 3/4"
2 29/32"
3 11/32
4 5/8
5 7/16" ±.032"
ZERO
6 7/8" ±.032"
CONNECTION BLOCKS
1"
1"
1/2"

PDWEW "5" CASE

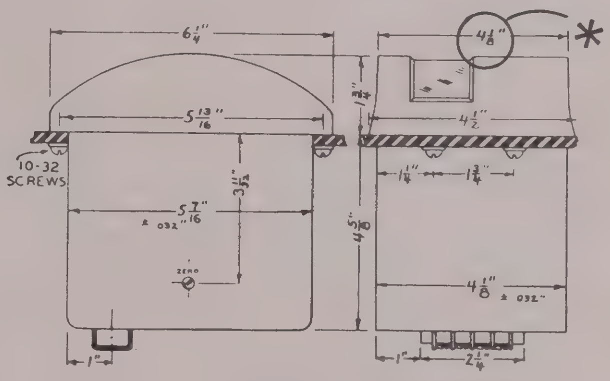
FOR MODEL PDW AND PDLW (3 phase wattmeters)



6 1/4"
2 23/32"
*
1 3/4"
5 13/16"
3 1/8"
10-32 SCREWS
3 11/32
3/4"
1 3/16
5 7/16" ±.032"
4 5/8
2 23/32" ± .032"
ZERO
CONNECTION BLOCK
1"
1/4"
2 1/4"

EW5 SHALLOW CASE

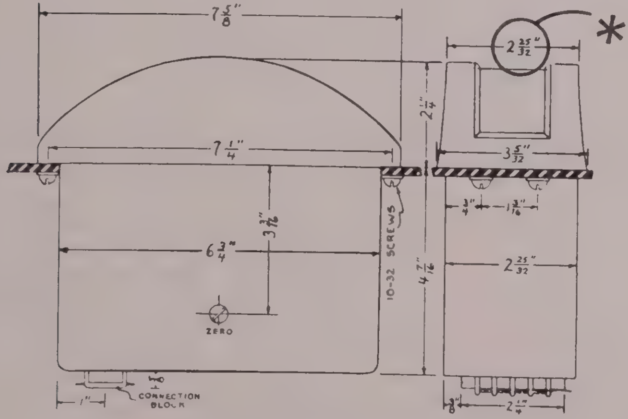
FOR MODELS S, A, HS, MI, FS, FM, SD, RA, AU, XT, RF AND FLV



6 1/4"
4 1/8"
*
1 3/4
5 13/16"
4 1/2"
10-32 SCREWS
3 11/32
1 1/4"
1 3/4"
5 7/16" ± .032"
4 5/8"
ZERO
4 1/8" ± .032"
1"
1"
2 1/4"

EW5 DEEP CASE

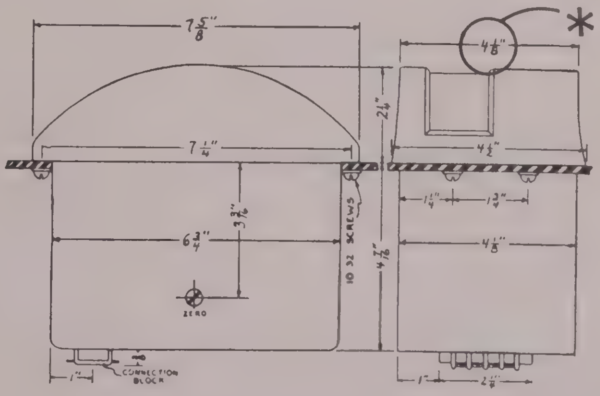
FOR MODELS D, DLW, DW, ESD, GM, DYSP AND FRE



7 5/8"
2 25/32
*
2 1/4"
7 1/4"
3 5/32"
3 7/16"
3/4"
1 3/16"
6 3/4"
10-32 SCREWS
4 7/16"
2 25/32"
ZERO
1/8
CONNECTION BLOCK
1"
1/8"
2 1/4"

EW7 SHALLOW CASE

FOR MODELS C. FLV, MI, FS, FM, RA



7 5/8"
4 1/8"
*
2 1/4"
7 1/4"
4 1/2"
3 7/16
1 1/4"
1 3/4"
6 3/4"
10 32 SCREWS
4 7/16
4 1/8"
ZERO
CONNECTION BLOCK
1"
1"
2 1/4"

EW7 DEEP CASE

FOR MODELS DW, D, DYSP, ESD AND FRE

No Dynamometer Wattmeters or Current instruments can be internally switch controlled (see page 133).

ACCURACIES IN THIS DESIGN CASE ARE THE SAME AS LISTED IN REGULAR MODEL PORTABLE INSTRUMENT.

NOTE: DUE TO SPACE LIMITATIONS, NO SAFETY KEY IS AVAILABLE ON THE NEW EDGEWISE PANEL INSTRUMENTS. (SEE PAGE 10)

* *WHEN INSTRUMENT IS SUPPLIED WITH INTERNAL SWITCH, THIS DIMENSION INCREASES BY 9/16" TO INCLUDE THE SWITCH KNOB.*

"SENSITIVE RESEARCH" FIELD ENGINEERING REPRESENTATIVES

HOME OFFICE
310 MAIN ST., NEW ROCHELLE, N. Y.
BEverly 5-2300

EARL LIPSCOMB ASSOCIATES
TRAVELAB
ELECTRONIC INSTRUMENTS

TYPICAL INTERIOR

EXPORT

AD. AURIEMA, INC.
85 Broad Street
New York 4, New York
Bowling Green 9-7750

EASTERN CANADA

MEL SALES LTD.
Arnprior, Ontario, Canada
Arnprior 400

P.O. Box 50, Don Mills
Toronto, Ontario
Hudson 1-0231

P.O. Box 1352, Postal Sta. "O"
Montreal, Quebec
St. Eustache 9198

WESTERN CANADA

ARVA, Inc.
Room 7-Marine Bldg.
355 Burrard Street
Vancouver 1, B. C., Canada

N. & S. CAROLINA — S. VIRGINIA

J. L. HIGHSMITH & CO.
737 Providence Rd.
Charlotte, North Carolina
Franklin 7-2546

CALIFORNIA, ARIZONA, NEVADA

McCARTHY ASSOCIATES
1055 East Walnut
Pasadena, California
Sycamore 2-8272

934 West Laurel Street
San Diego, California
Belmont 9-4015

635 Oak Grove Ave.
Menlo Park, California
Davenport 5-7937

GEORGIA, KENTUCKY, TENNESSEE, and ALABAMA

BIVINS & CALDWELL
3133 Maple Dr., N.E.
Atlanta 5, Georgia
Cedar 3-7522

Huntsville, Alabama
Jefferson 2-5733
(Direct line to Atlanta office)

FLORIDA

ARTHUR H. LYNCH AND ASSOCIATES

35 W. North Shore Ave
Fort Myers, Florida
Wyandotte 5-2151

P.O. Box 2492
Gainesville, Florida
Franklin 2-8028

NO. ILLINOIS and SO. WISCONSIN

SAFFRO & GETTLEMAN CO.
5209 No. Kimball Avenue
Chicago 25, Illinois
Juniper 8-0905

INDIANA

LAW INSTRUMENT COMPANY
P. O. Box 95
Angola, Indiana
217 & 8101-R

P.O. Box 6562
Indianapolis 27, Indiana
State 7-0009

KANSAS, WESTERN MISSOURI

HARRIS-HANSON COMPANY
7916 Paseo Avenue
Kansas City 30, Mo.
Hiland 4-9494

EASTERN MISSOURI, SOUTHERN ILLINOIS

HARRIS-HANSON COMPANY
2814 South Brentwood Blvd.
St. Louis 17, Mo.
Mission 7-4350

MICHIGAN

S. STERLING COMPANY
15310 W. McNichols Road
Detroit 35, Michigan
Broadway 3-2900

OHIO

S. STERLING COMPANY

5827 Mayfield Road
Cleveland 24, Ohio
Hillcrest 2-8080

363 W. First St.
Dayton 2, Ohio
Baldwin 8-8794

MINNESOTA, IOWA, NEBRASKA
N. & S. DAKOTA, NO. WISCONSIN

THE HEIMANN COMPANY
1711 Hawthorne Avenue
Minneapolis 3, Minnesota
Federal 2-5457

NEW MEXICO

GENE FRENCH COMPANY
120 San Pedro Drive S.E.
Albuquerque, New Mexico
Amherst 8-2478

PHILADELPHIA, EASTERN PENNA. & SOUTH NEW JERSEY

I. E. ROBINSON (Main Branch)
7404 West Chester Pike
Upper Darby, Penna.
Sherwood 8-1294

2120 Market St.
Camp Hill, Penna.
Regent 7-6791

905 Main St.
Asbury Park, New Jersey
Kellog 1-3150

CENTRAL NEW YORK

J. F. WULFETANGE, JR.
4505 E. Genesee St.
De Witt 14, New York
Gibson 6-3330

WESTERN NEW YORK

THE ROBERT F. LAMB CO.
1807 Elmwood Avenue
Buffalo 7, New York
Bedford 3757

NEW ENGLAND AND EASTERN N. Y.

YEWELL ASSOCIATES, INC.
Middlesex Turnpike
Burlington, Mass.
Browning 2-9000

1101 E. Main Street
Bridgeport, Conn.
Forest 6-3456

OREGON, WASHINGTON, IDAHO
W. MONTANA, ALASKA & HAWAII

ARVA, Inc.

120 West Thomas Street
Seattle 99, Washington
Atwater 4-7337

1238 N.W. Glisan
Portland 9, Oregon
CApitol 7-1281

PITTSBURGH, W. PA. AND W. VA.

S. STERLING COMPANY
4024 Clairton Blvd.
Pittsburgh 27, Penna.
Tuxedo 4-5515

TEXAS

EARL LIPSCOMB ASSOCIATES
P. O. Box 7084
Dallas, Texas
Fleetwood 7-1881

UTAH, COLORADO, WYOMING
& E. MONTANA

LAHANA AND COMPANY
1886 South Broadway
Denver 10, Colorado
Pearl 3-3791

WASHINGTON, D. C., MD. AND DEL

HORMAN ASSOCIATES, INC.
941 Rollins Avenue
Rockville, Maryland
Hazelwood 7-7560

3006 West Cold Spring Lane
Baltimore 15, Maryland
Mohawk 4-8345

Fourth Printing

Prices and specifications subject to change without notice.

A SENSITIVE RESEARCH

TRIPLE PLAY!

1. AC-DC WIDE RANGE CALIBRATOR

SRIC's versatile AC/DC Volt-Amp-Milliammeter "Self Checking" Model Thach is now offered in combination with a general purpose power supply for use as a convenient, economically priced, wide range instrument calibrator. The Model Thach has 19 overlapping full scale ranges of current and voltage. Operation is almost always at or near full scale for maximum accuracy. The power supply (Model Thach-PS) is a regulated source with its controls interlocked with the Model Thach. Power to the Thach is automatically shut off when ranges are switched, reducing the danger of accidently overloading the calibrator and/or the instrument under test. Output covers the full range of the Thach for DC and 60 cps. 50-2500 cps. can be plugged in for operation over a broader frequency range. Resolution of the power supply controls is better than .05% for any current and voltage range.

Any Model Thach with range combs. 1x or 3x is available for operation with the power supply. In addition, existing instruments in the field can be modernized for this same purpose at a small surcharge.

2. AC-DC LABORATORY STANDARD

The Model Thach can be used independently as a true RMS measuring instrument powered by any appropriate source. It checks its own accuracy against an internal standard cell, and is furnished completely self contained with a high sensitivity galvanometer. General specifications are as follows: Accuracy ± .2% F.S. (.1% at self-check points). Ranges 10/20/50/100/200/500 ma; 1/2/5 amps; 1/2/5/10/20/50/100/200/500/1000 v. Frequency range DC and 7 cps. to 4 kc. Sensitivity 100 ohms volt. Thermocouple D'Arsonval type. 100 division 6.3" hand drawn mirrored scale. Temperature compensated from 20°C.—30°C. 1000% manually operated overload protection system. Independent of influence of stray magnetic fields. Diamond Pivoted with sapphire shock mounted jewels. Furnished with 1 or 2 thermocouples. Available in two combinations: 1x is self checking at full scale only: 3x is self checking at 5 cardinal points including full scale. Size 16⅜" x 10½" x 8¾" deep. Weight approx. 21 lbs.

Model THACH AND THACH-PS

3. AC-DC GENERAL PURPOSE POWER SUPPLY

The Model Thach-PS, while designed primarily for operation with the Model Thach, can be used independently as a power source for any appropriate application. It only has to be disconnected from the Model Thach to become an excellent general purpose switch controlled laboratory supply.

SPECIFICATIONS:

OUTPUT: DC or AC (60 cps normal; 50-2500 cps depending on input) **Voltage**: Delivers 0-120% at full load and a max. of 0-175% at no load. 1/2/5 v. at 300 ma.; 10/20/50 v. at 100 ma.; 100/200/500/1000 v. at 25 ma. **Current**: 0-5 amps. at 15 watts max. on low power, or 75 watts max. on high power.

INPUT: 90-135 v., 60 cps single phase, or 115 v. 50-2500 cps from a regulated source.

WAVEFORM: 60 cps distortion 2.5% total harmonic content plus line distortion.

RIPPLE: Varies from .5% at full voltage and low currents to a maximum of 2.5% for currents of 1 ampere or less. At currents above 1 ampere, ripple can always be 3% or less if series resistance is sufficient in external circuit and will be no worse than 7% for any possible operation.

RESOLUTION: .05% or better by means of coarse, medium and fine controls.

SIZE: 12¾" x 17" x 9" deep.

WEIGHT: Approx. 59 lbs.

S

Symbol of Quality

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

ORDERING and PRICING INFORMATION

The Model THACH can be ordered separately or in combination with the Model THACH-PS power supply for use as a calibrator. Both units may be used independently even though modified to be operated together.

Existing Model THACH's in the field with range combinations 1X or 3X can be modified for use with the power supply. If thermocouple overloading is a problem, it is suggested that an instrument be converted whenever possible. It would be most convenient and economical to accomplish this conversion when the Model THACH is at Sensitive Research for normal servicing.

A. Model THACH for use as a measuring instrument. Specify by model, code word and price as listed below.

Comb.	Ranges	Code	No. of Internal Thermocouples	Price
1X	0 - 10/20/50/100/200/500 ma. 1/2/5 amps	CHEKALAB	1	$ 975.00
1X	0 - 1/2/5/10/20/50/100/200/500/1000 volts	DELABACHEK	2	1075.00
2X	0 - 15/30/75/150/300/750 ma. 1.5/3 amps	ACCURCHEK	1	875.00
2X	0 - 1.5/3/7.5/15/30/75/150/300/750 volts	ACCURMETER	2	975.00
3X	Same as Comb. 1X	MULTILAB	1	1175.00
3X	Same as Comb. 1X	DEMULTILAB	2	1375.00
4X	Same as Comb. 2X	MULTISELF	1	1075.00
4X	Same as Comb. 2X	DEMULTISELF	2	1275.00

Note 1: Combs. 3X and 4X are of the multichek design. They can be "Self Checked" to an accuracy of ±.1% not only for full scale deflection but at four additional points.

Note 2: Only the Combs. 1X and 3X can be modified for use with the Model THACH-PS power supply.

Note 3: Replacement standard cells with certification. Price $45.00.

B. Model THACH-PS for use as a general purpose power supply. Specify Model THACH-PS, Code THAPOS. Price $995.00.

C. Model THACH (Combs. 1X and 3X only) and Model THACH-PS modified for use as a combination calibrator, measuring instrument and/or general purpose power supply. Specify the models, the appropriate code words and the phrase "Combination Calibrator."

THACH Comb.	THACH Code	Total Price of Model THACH and THACH-PS Calibrator
1X	CHEKALAB	$2070.00
1X	DELABACHEK	2170.00
3X	MULTILAB	2270.00
3X	DEMULTILAB	2470.00

D. Model THACH-PS power supply for use with an existing Model THACH with range combinations 1X or 3X. Return Model THACH for modification. Specify on repair order, "Modify Model THACH and furnish Model THACH-PS." Price $1195.00. (Please note that this price does not include the cost of any additional repairs that may be necessary if the Model THACH is returned in need of other servicing.)

All prices subject to change without notice

Printed in U.S.A.

SENSITIVE RESEARCH INSTRUMENT CORPORATION

Symbol of Quality

NEW ROCHELLE, N. Y. *ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927*

'SENSITIVE RESEARCH' Field Engineers All Over The World!

Met. New York, No. New Jersey
SENSITIVE RESEARCH HOME OFFICE
New Rochelle, N. Y. Beverly 5-2300

Export (except Canada)
AD. AURIEMA, INC.
New York, N. Y. Bowling Green 9-7750

Eastern Canada
MEL SALES LTD.
Toronto, Ont. Hudson 1-0231
Montreal, Que. National 7-4313

Western Canada, Oregon, Washington, Idaho, W. Montana, Hawaii & Alaska
ARVA, INC.
Vancouver, B.C. Mutual 2-4323
Seattle, Wash. Main 2-0177
Portland, Ore. Capital 2-7337

No. & So. Carolina, So. Virginia
JAMES L. HIGHSMITH & CO.
Charlotte, No. Car. Franklin 7-2546

California, Arizona, Nevada
McCARTHY ASSOCIATES, INC.
Pasadena, Cal. Murray 1-7411
Menlo Park, Cal. Davenport 6-7937
San Diego, Cal. Broadway 4-1100
Phoenix, Ariz. Crestwood 9-1891

Ga., Kentucky, Tenn., Ala., Fla.
BIVINS & CALDWELL
Atlanta, Ga. Cedar 3-7522
Huntsville, Ala. Jefferson 2-5733
Orlando, Fla. Cherry 1-1091

No. Illinois & So. Wisconsin
SAFFRO & ASSOCIATES
Chicago, Ill. Juniper 8-0905

Indiana
LAW INSTRUMENT COMPANY
Angola, Ind. 217 & 8101-R
Indianapolis, Ind. State 7-0009

Kansas, West. Missouri, So. Ill.
HARRIS-HANSON COMPANY
Kansas City, Mo. Hiland 4-9494
St. Louis, Mo. Mission 7-4350

Michigan, Ohio, W. Penna., W. Va.
S. STERLING COMPANY
Detroit, Mich. Broadway 3-2900
Cleveland, O. Hillcrest 2-8080
Dayton, O. Baldwin 8-8794
Pittsburgh, Pa. Tuxedo 4-5515

Minnesota, Iowa, Nebraska, No. & So. Dakota, No. Wisconsin
THE HEIMANN COMPANY
Minneapolis, Minn. Federal 2-5457

New Mexico
GENE FRENCH COMPANY
Albuquerque, New Mexico Amherst 8-2478

Eastern Penna., So. New Jersey
I. E. ROBINSON COMPANY
Upper Darby, Penna. Sherwood 8-1294
Camp Hill, Penna. Regent 7-6791
Asbury Park, N. J. Kellog 1-3150

Central New York
J. F. WULFETANGE, JR.
De Witt, N. Y. Gibson 6-3330

Western New York
THE ROBERT F. LAMB COMPANY
Buffalo, N. Y. Bedford 3757

New England & Eastern New York
YEWELL ASSOCIATES, INC.
Burlington, Mass. Browning 2-9000
Bridgeport, Conn. Forest 6-3456
Poughkeepsie, N. Y. Grover 1-3456

Texas, Oklahoma, Louisiana, Arkansas & Mississippi
ARNOLD BARNES COMPANY
Dallas, Texas Lakeside 6-8735

Utah, Colo., Wyoming, East. Mont.
LAHANA & COMPANY
Denver, Colo. Pearl 3-3791
Salt Lake City, Utah Amherst 6-1721
Salt Lake direct line to Denver, Zenith 123

Washington, D.C., Maryland, Dela.
HORMAN ASSOCIATES, INC.
Rockville, Md. Hazelwood 7-7560
Baltimore, Md. Mohawk 4-8345

A SENSITIVE RESEARCH TRIPLE PLAY!

1. AC-DC WIDE RANGE CALIBRATOR

SRIC's versatile AC/DC Volt-Amp-Milliammeter "Self Checking" Model Thach is now offered in combination with a general purpose power supply for use as a convenient, economically priced, wide range instrument calibrator. The Model Thach has 19 overlapping full scale ranges of current and voltage. Operation is almost always at or near full scale for maximum accuracy. The power supply (Model Thach-PS) is a regulated source with its controls interlocked with the Model Thach. Power to the Thach is automatically shut off when ranges are switched, reducing the danger of accidently overloading the calibrator and/or the instrument under test. Output covers the full range of the Thach for DC and 60 cps. 50-2500 cps. can be plugged in for operation over a broader frequency range. Resolution of the power supply controls is better than .05% for any current and voltage range.

Any Model Thach with range combs. 1x or 3x is available for operation with the power supply. In addition, existing instruments in the field can be modernized for this same purpose at a small surcharge.

2. AC-DC LABORATORY STANDARD

The Model Thach can be used independently as a true RMS measuring instrument powered by any appropriate source. It checks its own accuracy against an internal standard cell, and is furnished completely self contained with a high sensitivity galvanometer. General specifications are as follows: Accuracy ± .2% F.S. (.1% at self-check points). Ranges 10/20/50/100/200/500 ma; 1/2/5 amps; 1/2/5/10/20/50/100/200/500/1000 v. Frequency range DC and 7 cps. to 4 kc. Sensitivity 100 ohms volt. Thermocouple D'Arsonval type. 100 division 6.3" hand drawn mirrored scale. Temperature compensated from 20°C. — 30°C. 1000% manually operated overload protection system. Independent of influence of stray magnetic fields. Diamond Pivoted with sapphire shock mounted jewels. Furnished with 1 or 2 thermocouples. Available in two combinations: 1x is self checking at full scale only: 3x is self checking at 5 cardinal points including full scale. Size 16⅜" x 10½" x 8¾" deep. Weight approx. 21 lbs.

Model THACH AND THACH-PS

3. AC-DC GENERAL PURPOSE POWER SUPPLY

The Model Thach-PS, while designed primarily for operation with the Model Thach, can be used independently as a power source for any appropriate application. It only has to be disconnected from the Model Thach to become an excellent general purpose switch controlled laboratory supply.

SPECIFICATIONS:

OUTPUT: DC or AC (60 cps normal; 50-2500 cps depending on input) **Voltage**: Delivers 0-120% at full load and a max. of 0-175% at no load. 1/2/5 v. at 300 ma.; 10/20/50 v. at 100 ma.; 100/200/500/1000 v. at 25 ma. **Current**: 0-5 amps. at 15 watts max. on low power, or 75 watts max. on high power.

INPUT: 90-135 v., 60 cps single phase, or 115 v. 50-2500 cps from a regulated source.

WAVEFORM: 60 cps distortion 2.5% total harmonic content plus line distortion.

RIPPLE: Varies from .5% at full voltage and low currents to a maximum of 2.5% for currents of 1 ampere or less. At currents above 1 ampere, ripple can always be 3% or less if series resistance is sufficient in external circuit and will be no worse than 7% for any possible operation.

RESOLUTION: .05% or better by means of coarse, medium and fine controls.

SIZE: 12¾" x 17" x 9" deep.

WEIGHT: Approx. 59 lbs.

S

Symbol of Quality

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

ORDERING and PRICING INFORMATION

The Model THACH can be ordered separately or in combination with the Model THACH-PS power supply for use as a calibrator. Both units may be used independently even though modified to be operated together.

Existing Model THACH's in the field with range combinations 1X or 3X can be modified for use with the power supply. If thermocouple overloading is a problem, it is suggested that an instrument be converted whenever possible. It would be most convenient and economical to accomplish this conversion when the Model THACH is at Sensitive Research for normal servicing.

A. Model THACH for use as a measuring instrument. Specify by model, code word and price as listed below.

Comb.	Ranges	Code	No. of Internal Thermo-couples	Price
1X	0 - 10/20/50/100/200/500 ma. 1/2/5 amps	CHEKALAB	1	$ 975.00
1X	0 - 1/2/5/10/20/50/100/200/500/1000 volts	DELABACHEK	2	1075.00
2X	0 - 15/30/75/150/300/750 ma. 1.5/3 amps	ACCURCHEK	1	875.00
2X	0 - 1.5/3/7.5/15/30/75/150/300/750 volts	ACCURMETER	2	975.00
3X	Same as Comb. 1X	MULTILAB	1	1175.00
3X	Same as Comb. 1X	DEMULTILAB	2	1375.00
4X	Same as Comb. 2X	MULTISELF	1	1075.00
4X	Same as Comb. 2X	DEMULTISELF	2	1275.00

Note 1: Combs. 3X and 4X are of the multichek design. They can be "Self Checked" to an accuracy of ±.1% not only for full scale deflection but at four additional points.

Note 2: Only the Combs. 1X and 3X can be modified for use with the Model THACH-PS power supply.

Note 3: Replacement standard cells with certification. Price $45.00.

B. Model THACH-PS for use as a general purpose power supply. Specify Model THACH-PS, Code THAPOS. Price $995.00.

C. Model THACH (Combs. 1X and 3X only) and Model THACH-PS modified for use as a combination calibrator, measuring instrument and/or general purpose power supply. Specify the models, the appropriate code words and the phrase "Combination Calibrator."

THACH Comb.	THACH Code	Total Price of Model THACH and THACH-PS Calibrator
1X	CHEKALAB	$2070.00
1X	DELABACHEK	2170.00
3X	MULTILAB	2270.00
3X	DEMULTILAB	2470.00

D. Model THACH-PS power supply for use with an existing Model THACH with range combinations 1X or 3X. Return Model THACH for modification. Specify on repair order, "Modify Model THACH and furnish Model THACH-PS." Price $1195.00. (Please note that this price does not include the cost of any additional repairs that may be necessary if the Model THACH is returned in need of other servicing.)

All prices subject to change without notice

Printed in U.S.A.

S

Symbol of Quality

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N.Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

'SENSITIVE RESEARCH' Field Engineers All Over The World!

Met. New York, No. New Jersey
SENSITIVE RESEARCH HOME OFFICE
New Rochelle, N. Y. Beverly 5-2300

Export (except Canada)
AD. AURIEMA, INC.
New York, N. Y. Bowling Green 9-7750

Eastern Canada
MEL SALES LTD.
Toronto, Ont. Hudson 1-0231
Montreal, Que. National 7-4313

Western Canada, Oregon, Washington, Idaho, W. Montana, Hawaii & Alaska
ARVA, INC.
Vancouver, B.C. Mutual 2-4323
Seattle, Wash. Main 2-0177
Portland, Ore. Capital 2-7337

No. & So. Carolina, So. Virginia
JAMES L. HIGHSMITH & CO.
Charlotte, No. Car. Franklin 7-2546

California, Arizona, Nevada
McCARTHY ASSOCIATES, INC.
Pasadena, Cal. Murray 1-7411
Menlo Park, Cal. Davenport 6-7937
San Diego, Cal. Broadway 4-1100
Phoenix, Ariz. Crestwood 9-1891

Ga., Kentucky, Tenn., Ala., Fla.
BIVINS & CALDWELL
Atlanta, Ga. Cedar 3-7522
Huntsville, Ala. Jefferson 2-5733
Orlando, Fla. Cherry 1-1091

No. Illinois & So. Wisconsin
SAFFRO & ASSOCIATES
Chicago, Ill. Juniper 8-0905

Indiana
LAW INSTRUMENT COMPANY
Angola, Ind. 217 & 8101-R
Indianapolis, Ind. State 7-0009

Kansas, West. Missouri, So. Ill.
HARRIS-HANSON COMPANY
Kansas City, Mo. Hiland 4-9494
St. Louis, Mo. Mission 7-4350

Michigan, Ohio, W. Penna., W. Va.
S. STERLING COMPANY
Detroit, Mich. Broadway 3-2900
Cleveland, O. Hillcrest 2-8080
Dayton, O. Baldwin 8-8794
Pittsburgh, Pa. Tuxedo 4-5515

Minnesota, Iowa, Nebraska, No. & So. Dakota, No. Wisconsin
THE HEIMANN COMPANY
Minneapolis, Minn. Federal 2-5457

New Mexico
GENE FRENCH COMPANY
Albuquerque, New Mexico Amherst 8-2478

Eastern Penna., So. New Jersey
I. E. ROBINSON COMPANY
Upper Darby, Penna. Sherwood 8-1294
Camp Hill, Penna. Regent 7-6791
Asbury Park, N. J. Kellog 1-3150

Central New York
J. F. WULFETANGE, JR.
De Witt, N. Y. Gibson 6-3330

Western New York
THE ROBERT F. LAMB COMPANY
Buffalo, N. Y. Bedford 3757

New England & Eastern New York
YEWELL ASSOCIATES, INC.
Burlington, Mass. Browning 2-9000
Bridgeport, Conn. Forest 6-3456
Poughkeepsie, N. Y. Grover 1-3456

Texas, Oklahoma, Louisiana, Arkansas & Mississippi
ARNOLD BARNES COMPANY
Dallas, Texas Lakeside 6-8735

Utah, Colo., Wyoming, East. Mont.
LAHANA & COMPANY
Denver, Colo. Pearl 3-3791
Salt Lake City, Utah Amherst 6-1721
Salt Lake direct line to Denver, Zenith 123

Washington, D.C., Maryland, Dela.
HORMAN ASSOCIATES, INC.
Rockville, Md. Hazelwood 7-7560
Baltimore, Md. Mohawk 4-8345

A CASE OF *Accuracy!*

NEW!
SENSITIVE RESEARCH
COMMANDER
S
INSTRUMENTS
Type SR21
Type 9152
Type 5214
Type 9700
Type 9144

The "COMMANDER" instruments described below have a 5-year accuracy guarantee. By using NBS or NRC reported values, total cumulative errors for a complete measurement system can be as low as ±.002%.

DAUPHINEE POTENTIOMETER TYPE 9144

ACCURACY ±.001%

A 7-figure (above 1 V.) DC vernier potentiometer with a total measuring range of 2.101010V. *Accuracy is at least 10 x that of similar commercially available equipment.* Direct readout on 4 dials in increments of .1 μv (no slidewire). Thermal emf's less than .1 μv. Switch controlled ranges of x 1 & x .1. Contains 2 saturated standard cells in an internally thermostated enclosure. Completely "Self-Checking." *May be used with equal facility and accuracy as a Saturated Standard Cell or Resistance Comparator — and for the calibration of .01% accurate potentiometers.*

The Type 9144 is an original design by Dr. T. M. Dauphinee of the National Research Council in Canada. All rights are protected by a United States patent application.

VOLT RATIO BOX TYPE 9700

ACCURACY ±.005%

A volt ratio box similar to that used by the National Bureau of Standards as described by NBS Research Paper RP 1419. Self-heating and surface leakage negligible. Ranges: .15/.3/.45/.6/.75/1.5/3/4.5/6/7.5/15/30/45/60/75/150/300/450/600/750 V. (Type 9700A includes 1500 V. range). Furnished in a thermostated oil bath with a motor-driven impeller.

CONSTANT TEMPERATURE STANDARD CELL ENCLOSURE TYPE 9152 AND SATURATED STANDARD CELL TYPE 4305

ACCURACY ±.001%

Enclosure accommodates up to 4 cells and is air thermostated at 28°C ± .025°C. Transistorized circuit. Operates on 110V/60 cps (Battery standby).

THE TYPE 5214 GALVANOMETER AMPLIFIER AND TYPE SR21 LIGHT SPOT GALVANOMETER.

The amplifier operates on the differential photocell principle in conjunction with a liquid-filled primary galvanometer. The secondary galvanometer has a scale length of 120-0-120 mm and is stable and free from the effects of external vibration. Over-all sensitivity is approximately 350,000 mm/μa and 35,000 mm/μv. It is ideally suited for use with the type 9144 potentiometer.

Sensitive Research "COMMANDER" Instruments are manufactured by Guildline Instruments, Ltd. (formerly Tinsley Instruments (Canada) Ltd.)

S

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

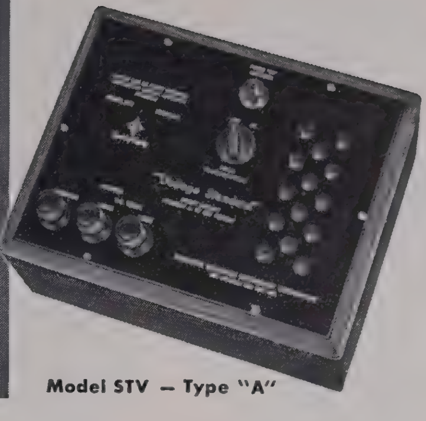
Symbol of Quality

A Personal Invitation
to visit Sensitive Research
at the **N. E. C.** *Show, Chicago, Ill.*

Booth 501

October 10-12 **Sherman Hotel**

NEW!
SENSITIVE RESEARCH
.01% ACCURATE
.005% STABLE



Model STV — Type "A"

D.C. VOLTAGE STANDARD

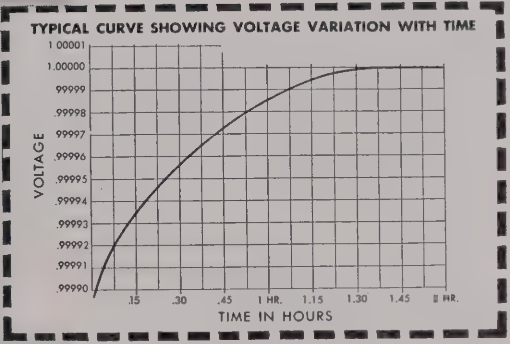
All SRIC instruments are calibrated against primary standards that have National Bureau of Standards Certificates of Accuracy and are unconditionally guaranteed for a period of one year.

The Model STV is an extremely accurate and stable reference source for use with "null balance" devices such as potentiometers and other infinite impedance comparators. It is at least equivalent in accuracy to the best unsaturated standard cells and is superior in almost all other respects to both saturated and unsaturated types.

While the Model STV is essentially a zero current drain source, it may be operated into any impedance without damage. It can be short circuited indefinitely without affecting accuracy or life expectancy, and it will almost instantaneously regain its original open circuit voltage when the short is removed. For calculating output current, the Model STV may be considered a perfect voltage source in series with a 2000 ohm resistance; thus the maximum current when short circuited is .5 ma. Special units are available for use as Standard Current sources into specific external resistances.

The accuracy of the Model STV is unaffected by vibration from transportation, exposure to extremes of temperature, or changes in operating position.

TYPICAL CURVE SHOWING VOLTAGE VARIATION WITH TIME



SPECIFICATIONS — Type "A"

Input: 90-135 Volts AC; 60 cps; 25 va.

Output: 1.0000 Volt and 1.0185 Volts D.C.

Accuracy: ±.01% of nominal output (furnished with actual output certified to .001%).

Stability: ±.005% of actual output for 100-125 Volts input and 20°-30°C.
±.01% for 90-140 Volts input and 15°-35°C.

Temperature Range: 15°-35°C (Operates with reduced accuracy beyond these limits, but with its output exactly reproducible).

Operational Life: 25,000 hours minimum.

Size: 9⅜"x7⅝"x5". **Weight:** 10 lbs.

Price: $219.00

Type "B"

Rack Panel Mounting Voltage Standard. Specifications same as Type "A" except mounted on 19"x5¼"x5⁄16" bakelite panel. **Price:** $234.00

Model STV — Types C & D

Types C & D Model STV units are designed specifically for use in new or existing O.E.M. instruments. Output, accuracy and stability are exactly equivalent to Type A units.

SPECIFICATIONS — Type "C"

Input: 115 V.A.C. ±1%; 50-500 cps; 25 va.

Size: 3"x3"x3½" high, deep drawn aluminum case for chassis mounting.

Output: Accuracy and other specifications exactly as listed for Type "A".

Price: $176.00

Type "D"

Input: 150 Volts D.C. ±1%.

Size: Same as Type "C" above.

Output: Accuracy and other specifications exactly as listed for Type "A".

Price: $171.00

SPECIAL UNITS

Special reference sources are available with any voltage output up to 7.5 volts. Correspondence is invited on special requirements to even higher voltages.

SENSITIVE RESEARCH INSTRUMENT CORPORATION

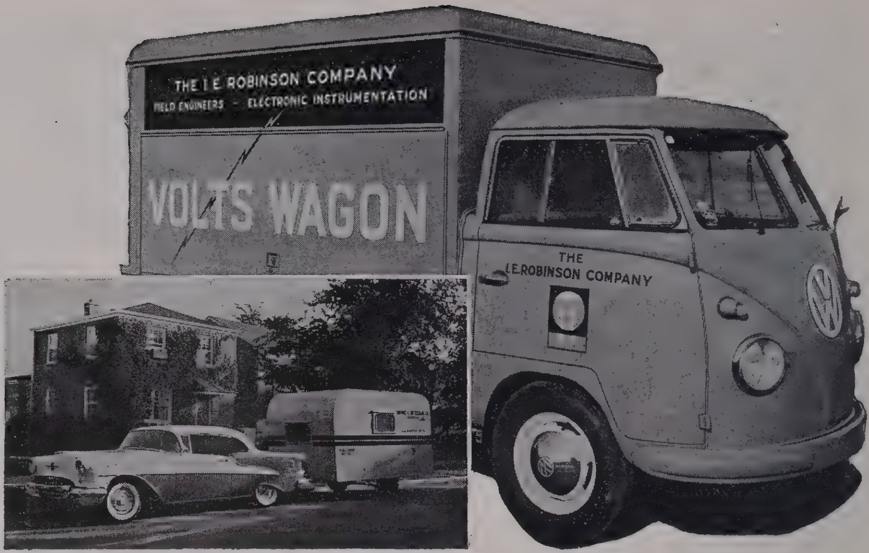
S
Symbol of Quality

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

"SENSITIVE RESEARCH" FIELD ENGINEERING REPRESENTATIVES

HOME OFFICE
310 MAIN ST., NEW ROCHELLE, N. Y
BEverly 5-2300
Metropolitan New York,
Westchester, Putnam & Rockland Counties,
Long Island and Northern New Jersey


THE I.E. ROBINSON COMPANY
FIELD ENGINEERS - ELECTRONIC INSTRUMENTATION
VOLTS WAGON
THE I.E. ROBINSON COMPANY

EXPORT

AD. AURIEMA, INC.
85 Broad Street
New York 4, New York
Bowling Green 9-7750

EASTERN CANADA

MEL SALES LTD.

1969 Avenue Rd.
Toronto 12, Ontario
Hudson 1-0231

P.O. Box 1352, Postal Sta. "O"
Montreal, Quebec
National 7-4313

WESTERN CANADA

ARVA, Inc.
Room G-7 — Marine Bldg.
355 Burrard Street
Vancouver 1, B.C., Canada
Mutual 2-4323

N. & S. CAROLINA — S. VIRGINIA

JAMES L. HIGHSMITH & CO.
3733 Monroe Rd.
Charlotte 5, North Carolina
Franklin 7-2546

CALIFORNIA, ARIZONA, NEVADA

McCARTHY ASSOCIATES, Inc.

1055 East Walnut
Pasadena, California
Ryan 1-7411

635 Oak Grove Ave.
Menlo Park, Calif.
Davenport 6-7937

3460 Ingraham St.
San Diego, California
Broadway 4-1100

111 Osborn West
Suite 213
Phoenix, Arizona
Crestwood 9-1891

GEORGIA, KENTUCKY, TENNESSEE, and ALABAMA

BIVINS & CALDWELL
3133 Maple Dr., N.E.
Atlanta 5, Georgia
Cedar 3-7522

Huntsville, Alabama
Jefferson 2-5733
(Direct line to Atlanta office)

FLORIDA

BIVINS & CALDWELL
723 W. Smith St.
Orlando, Florida
Cherry 1-1091

NO. ILLINOIS and SO. WISCONSIN

SAFFRO & ASSOCIATES
5209 No. Kimball Avenue
Chicago 25, Illinois
Juniper 8-0905

INDIANA

LAW INSTRUMENT COMPANY
P. O. Box 95
Angola, Indiana
217 & 8101-R

P.O. Box 6562
Indianapolis 27, Indiana
State 7-0009

KANSAS, WESTERN MISSOURI

HARRIS-HANSON COMPANY
7916 Paseo Avenue
Kansas City 30, Mo.
Hiland 4-9494

EASTERN MISSOURI, SOUTHERN ILLINOIS

HARRIS-HANSON COMPANY
2814 South Brentwood Blvd.
St. Louis 17, Mo.
Mission 7-4350

MICHIGAN

S. STERLING COMPANY
15310 W. McNichols Road
Detroit 35, Michigan
Broadway 3-2900

OHIO

S. STERLING COMPANY

5827 Mayfield Road
Cleveland 24, Ohio
Hillcrest 2-8080

363 W. First St.
Dayton 2, Ohio
Baldwin 8-8794

MINNESOTA, IOWA, NEBRASKA
N. & S. DAKOTA, NO. WISCONSIN

THE HEIMANN COMPANY
1711 Hawthorne Avenue
Minneapolis 3, Minnesota
Federal 2-5457

NEW MEXICO

GENE FRENCH COMPANY
120 San Pedro Drive S.E.
Albuquerque, New Mexico
Amherst 8-2478

PHILADELPHIA, EASTERN PENNA. & SOUTH NEW JERSEY

I. E. ROBINSON (Main Branch)
7404 West Chester Pike
Upper Darby, Penna.
Sherwood 8-1294

2120 Market St.
Camp Hill, Penna.
Regent 7-6791

905 Main St.
Asbury Park, New Jersey
Kellog 1-3150

CENTRAL NEW YORK

J. F. WULFETANGE, JR.
4505 E. Genesee St.
De Witt 14, New York
Gibson 6-3330

WESTERN NEW YORK

THE ROBERT F. LAMB CO.
3407 Delaware Ave.
Buffalo 17, New York
Bedford 3757

NEW ENGLAND AND EASTERN N. Y.

YEWELL ASSOCIATES, INC.

Middlesex Turnpike
Burlington, Mass.
Browning 2-9000

1101 E. Main St.
Bridgeport, Conn.
Forest 6-3456

806 Main St.
Poughkeepsie, N. Y.
Grover 1-3456

OREGON, WASHINGTON, IDAHO,
W. MONTANA, HAWAII & ALASKA

ARVA, Inc.

1320 Prospect St.
Seattle 9, Wash.
Main 2-0177

1238 N.W. Glisan
Portland 9, Oregon
CApitol 2-7337

PITTSBURGH, W. PA. AND W. VA.

S. STERLING COMPANY
4024 Clairton Blvd.
Pittsburgh 27, Penna.
Tuxedo 4-5515

TEXAS, OKLAHOMA, LOUISIANA,
ARKANSAS & MISSISSIPPI

ARNOLD BARNES CO.
3603 Lemmon Ave.
Dallas 19, Texas
Lakeside 6-8735

UTAH, COLORADO, WYOMING
& E. MONTANA

LAHANA AND COMPANY

1886 So. Broadway
Denver 10, Colo.
Pearl 3-3791

1332 Warden Way W.
Salt Lake City, Utah
Amherst 6-1721

Salt Lake direct line to Denver, Zenith 123

WASHINGTON, D. C., MD. AND DEL.

HORMAN ASSOCIATES, INC.

941 Rollins Avenue
Rockville, Maryland
Hazelwood 7-7560

3006 West Cold Spring Lane
Baltimore 15, Maryland
Mohawk 4-8345

Printed in U.S.A.

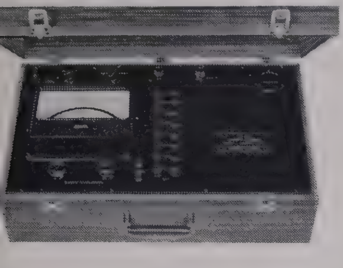
Third Printing

Prices and specifications subject to change without notice.

Instruments on Display at Booth Nos. 3409-3411, N.Y. IRE

NEW!

AC/DC TRANSFER STANDARD



Model FLH — Portable AC/DC difference tester ideally suited for the certification of other transfer standards, or when used with precision DC potentiometers, for the high accuracy measurement of AC voltages. Maximum frequency influence ±.05% to 50 kc. Furnished with NBS correction figures to a certified accuracy of ±.01%. Multipliers used are selected for superior performance over a wide frequency range. Long term stability is not a factor in over-all accuracy.

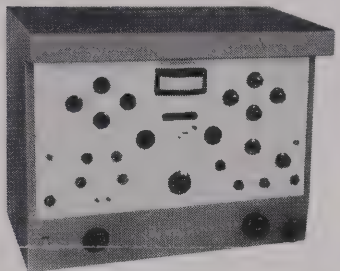
Ranges: 1.5-3/7.5/15/30/75/150/300/750 V. (Nominal overloads of 50% will not affect operation and, therefore, 750 V range may be used for 1000 V measurements.

Sensitivity: 100 Ω/V

Resolution: .005%

NEW!

AC/DC CALIBRATION CONSOLE



Model LTC-1 — Second edition in a series of high accuracy test consoles. Features additional advantages of automatic overload protection and packaging in an aluminum shielded case. The **only** instrument with **all** the standout specifications listed below:

Accuracy: ±.05% of reading DC to 25 kc

Current Range: 1 ma to 11.11 amperes

Voltage Range: .5 v to 1111 V

Readout: Directly in "% Error" or in actual figures.

Self contained for one-man operation.

Model LT-PS-1 is a low distortion (.1% 25%), highly stable (±.01%), variable frequency (20 cps-2okc) power supply for use with LTC.

NEW!

AC/DC POLYRANGER

Model UX — Versatile 51 range portable electrical indicating instrument with increased scale resolution and long term performance reliability. Features AC expanded scale, 1000% automatic overload protection and a completely self contained "Self Checking" system. Diamond Pivoted of course!

DC Ranges: 5/10/20/50/100/200/500 mv; 1/2/5/10/20/50/100/200/500/1000 v; .2/.5/1/2/5/10/20/50/100/200/500 ma; 1/2/5 amps.

AC Ranges: .5/1/2/5/10/20/50/100/200/500/1000 v; 10/20/50/100/200/500 ma; 1/2/5 amps.

Accuracy: DC .5%; AC .75% to 5 kc on voltage and 15 kc on current.

Sensitivity: DC 5000 Ω/v; AC 100 Ω/v.

NEW!

POCKETPOT

Model PC — Miniature DC potentiometer for use as an infinite impedance calibrator and measuring instrument. Self contained reference source, galvanometer and direct "in line" dial readout. Available with Model PC-1 volt-amp-milliampere "plug in" range extension unit of same size. Single leather carrying case for both items.

Accuracy: ±.05% of reading

Range: .01 — 5.09 V

Range Extension Unit: 5/50/500 V (500 Ω/v); .5/5/50/500 ma, 1 amp. Accuracy ±.05%

Resolution: .01 V

Size: 9" x 4¼" x 1¾" each unit

SENSITIVE RESEARCH

NEW!

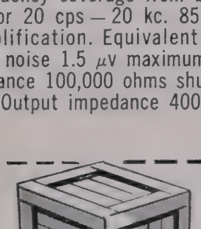
FREQUENCY SELECTIVE AMPLIFIER

Commander Type 5212M—Null-detector for use with AC bridges, potentiometers and other such devices. Continuous frequency coverage from 10 cps — 10 kc or 20 cps — 20 kc. 85 to 100 db amplification. Equivalent Q,30. Hum and noise 1.5 μv maximum. Input impedance 100,000 ohms shunted by 10 pF. Output impedance 400 ohms.

NEW!

VARIABLE STANDARD INDUCTOR

Commander Types 9001, 9011 and 9111 precision mutual inductor with ranges of .1 μh — 1.111 mh, 1 μh — 11.11 mh and 10 μh — to 111.1 mh. Low capacitance construction features stranded silk-covered copper wire, wound on marble formers. Accuracy ±.02% to ±.05% DC to 1000 cps.



Plus-a *NEW* new item to be released at the show.

RECENTLY INTRODUCED:

Type 9144 — Dauphinee 6 figure ±.001% accurate DC potentiometer.

Model INCRE — Expanded scale DC volt-milliamp meter; 70" scale length; accuracy .05%.

Type 9152 — Saturated standard cell enclosure; temperature controlled to ±.01°C.

Type 4305 — Saturated standard cell.

Model THACH 3X — Self-checking AC-DC volt-amp-milliammeter; ±.2% accuracy.

Model THACH-PS — AC-DC overload protected power supply for use with Model THACH.

Types 5214 & SR21 — Galvanometer and amplifier; sensitivity up to 1750 mm/μv.

Model FM — Multirange fluxmeter; ±.5% f.s. accuracy.

Model N — AC-DC volt-amp-milliamp meters; 6.1" scale length; ±.5% f.s. accuracy.

Model 2-AP — Overload protected Polyranger (up to 7000%); ±.75% f.s. accuracy.

Type 9744 — Precision chopper; thermal emf's less than .01/μv.

Type 9742/3 — Miniaturized low thermal choppers.

Type 9700A — N.B.S. type volt ratio box; ±.005% accuracy.

Precision AC and DC reference standards for the measurement of current, voltage, power, power factor, frequency and magnetic quantities.

NEW ROCHELLE, N. Y. *ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927*

PRINTED IN U.S.A

EVERYONE!...

IS GETTING READY TO VISIT

SENSITIVE RESEARCH

AT THE NEW YORK IRE

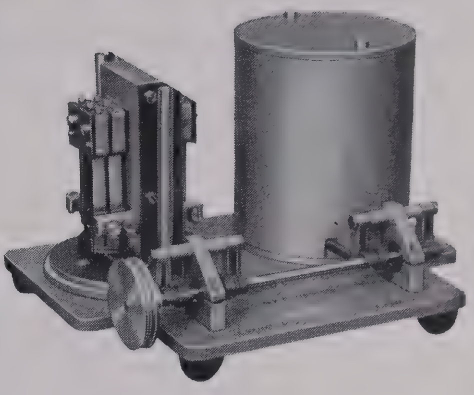
BOOTH NOS. 3409-3411

COLISEUM **MARCH 20-23**

NEW! SENSITIVE RESEARCH "COMMANDER" INSTRUMENTS

LOW THERMAL CHOPPERS

The Types 9742, 9743, and 9744 Low Thermal Choppers have resulted from design work accomplished at the National Research Council in Ottawa, Canada. Their construction makes them particularly adaptable to circuits where thermal noise is of importance, such as in low level DC amplifier applications and Hall Effect measurements.



Type 9744
with one cylinder removed

SPECIFICATIONS

THERMAL EMFs: *0.02 µv or less.*

CONSTRUCTION: Contain 2 (Type 9742), 3 (Type 9743), or 4 (Type 9744) DPDT switches, all actuated by a common shaft. Switch arms are made of copper. Contacts are solid gold blocks. Switch sections are separated by electrostatic screens and surrounded by heavy metal covers to maintain thermal equilibrium. The Type 9743 is particularly adaptable for OEM applications because of its small size (3½" x 5¼" x 4" high).

RELATIVE PHASE OF SWITCHES: Adjustable through 360° by rotating the cams on the shaft.

MAKE/BREAK RATIO: Each contact can be separately adjusted from 0 to 100% of a cycle with an accuracy of ±1%.

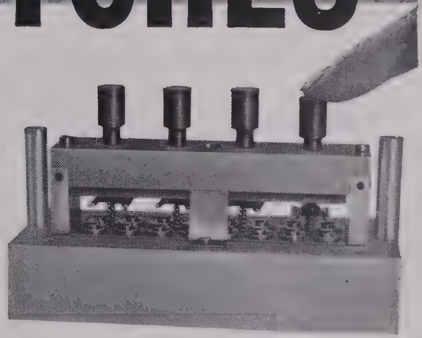
CURRENT CAPACITY: Depends whether circuit is resistive, capacitative or inductive. Will usually operate in purely resistive circuits to interrupt up to 100 millivolt amperes. Correspondence necessary for special applications.

CHOPPING FREQUENCIES: Speeds up to 60 cps. are normal. Optimum speed depends on applications, i.e. in a DC amplifier operating from a 60 cycle supply, a maximum rejection of 60 cycle pick-up can be obtained at a speed of approximately 37.5 cps. Speeds up to 90 cps. can be used by increasing the tension of the spring on the rod return.

DRIVING MECHANISM: A small synchronous motor capable of a 0.8 inch-oz. torque. (Not furnished)

LOW THERMAL SWITCHES

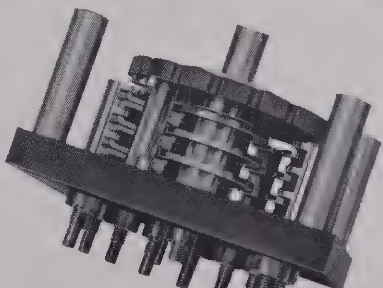
The Type 9145 Low Thermal Selector Switch is intended for use in potentiometer or other circuits where the generation of stray emfs must be kept to an absolute minimum. Its construction (based upon an ingenious design by Dr. T. M. Dauphinee of the National Research Council in Canada) assures a positive circuit connection by the use of self-wiping contacts while the generation of thermal emfs under all possible conditions is limited to less than 0.01 µv. The switch contains 4 DPST sections with all tellurium-copper contacts and is mounted in a solid block of aluminum to minimize temperature gradients. Operation is made simple by allowing for the selection of any one of 4 circuits by merely depressing a push button. The buttons lock down automatically and release when any other button is depressed. Two or more buttons may be simultaneously depressed if desired. A separate release button is provided to open all circuits. The terminals can be cross connected for applications requiring a reversing switch.



Type 9145 with panel & case removed

Dual Contact Switches. A wide variety of standard and special self-cleaning dual contact switches are available for transfer and/or reversing applications demanding the highest degree of precision and reliability.

The complete wiper or brush is made up of two assemblies, each with 8 individually sprung contact arms that are separated and riveted together at the center. The elasticity of the wiper arms maintains the whole assembly against the inner surfaces of the center segments of the brush and the stationary contacts. This arrangement effectively allows the wiper to "float" between the stationary contacts since it is not mechanically held in place other than by the pressure of its own individually sprung arms. Hence, contact pressure and contact resistance is always constant. All copper contacts are used when low resistance or thermoelectric free switches are required. The generation of thermal emfs can be kept as low as .01 µv. For exceptionally low resistance applications, the wiper assemblies can be paralleled. Switches with copper contacts have a resistance as low as 100 microhms between soldering points and will vary less than 10 microhms between contact points.



Dual Contact Switch

The Type 9600 Low Thermal Reversing Switch with oil immersed all copper contacts simplifies and speeds up the operation of precision potentiometers. By a single turn of the switch the potentiometer battery and two measuring circuits are reversed and the galvanometer is disconnected during the change over. If only one measuring circuit is in use the spare section of the switch can be utilized to reverse the standard cell and thus make it possible to check the standardization of the potentiometer with either a + or − connection of the battery. In the battery circuit the switch contacts do not introduce a change in resistance large enough to significantly affect the potentiometer current. The maximum change of contact resistance on reversal does not exceed 100 µΩ. In a typical potentiometer of 100 Ω resistance this would cause a change in current of 1 ppm.

ALL "COMMANDER" INSTRUMENTS ARE MANUFACTURED FOR SENSITIVE RESEARCH BY GUILDLINE INSTRUMENTS, LTD. — FORMERLY TINSLEY INSTRUMENTS (CANADA) LTD.

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

Electrical Instruments of Precision Since 1927

S
Symbol of Quality

ORDERING and PRICING INFORMATION

Sensitive Research "COMMANDER" Instruments

CHOPPERS and SWITCHES

DESCRIPTION	TYPE NO.	PRICE*
Low Thermal Chopper (2 DPDT Switches)	9742	$295
Low Thermal Chopper (3 DPDT Switches, miniaturized version)	9743	381
Low Thermal Chopper (4 DPDT Switches)	9744	500
Low Thermal Selector Switch	9145	343
Reversing Switch	9600	440
Dual Contact Switches (copper contacts only)		Listed below

Low Thermal Copper Switches	Poles	5/16" Stud Diam.			3/8" Stud Diam.			1/2" Stud Diam.		
		Base Price 2 Pos.	Add. Price Per Pos.	Max. Poss. Pos.	Base Price 2 Pos.	Add. Price Per Pos.	Max. Poss. Pos.	Base Price 2 Pos.	Add. Price Per Pos.	Max. Poss. Pos.
SINGLE BRUSH	1	$ 63	$ 1	25	$ 67	$ 1.50	25	$ 73	$ 2	16
	2	81	2.50	12	83	4	12	85	6	6
	3	95	10	7	98	14	6	104	8	3
	4	106	15	4	126	17	4	147	—	—
DOUBLE BRUSH	1				$ 77	$ 2	25	$ 80	$ 3	16
	2				95	5	12	97	9	6
	3				113	16	6	116	16	3
	4				146	21	4	168	—	—
TRIPLE BRUSH	1							$256	$ 7	11

* Prices include customs duty, brokerage, packaging, conversion to American dollars and all other special handling charges.

EXEMPTION FROM BUY AMERICAN ACT

All "COMMANDER" instruments are of Canadian origin and come under Federal Class Code 6625. In accordance with ASPR 6-103 and 6-104, the Buy American Act restriction for military procurement is waived, and "COMMANDER" instruments are considered as United States equipment.

DUTY FREE ENTRY OF "COMMANDER" INSTRUMENTS

Duty free certificates can be obtained for "COMMANDER" instruments in accordance with ASPR 6-605 (Revised Oct. 1, 1959). Where the material requisitioned is for purposes of National Defense, duty free entry can be accorded Canadian supplies upon proper application of the cognizant contracting governmental agency.

Duty Free Certificates cannot be issued where the duty is less than $50.00.

DUTY FREE PRICES

Special quotations will be given in those cases where a duty free certificate is applicable.

WARRANTY

Potentiometers, Bridges, Volt Ratio Boxes and Standard Resistors are warranted for five years, all other models for one year.

CERTIFICATION BY NBS OR NRC

"COMMANDER" instruments may be forwarded for certification to either the National Bureau of Standards in Washington, D. C., or Boulder, Colorado, or the National Research Council in Ottawa, Canada. In the case of NBS, it is preferable that purchase orders for such services be made out directly to that organization. Quotations can be issued by Sensitive Research to cover all testing accomplished by NRC.

ORDERING INFORMATION

Orders should be made out to Sensitive Research Instrument Corporation, 310 Main St., New Rochelle, N. Y.

Terms: Net 30 days. F.O.B.: Rouses Point, N. Y.

In addition to the choppers and switches listed above, a wide variety of AC and DC potentiometers, standard resistors, inductors, volt ratio boxes, saturated standard cells, constant temperature enclosures, galvanometers, bridges, temperature measuring instruments and many other fine electrical measuring standards are described in detail in the new SRIC "COMMANDER" Catalog. Copies are available from your local Sensitive Research representative.

Printed in U.S.A.

Prices subject to change without notice.

Symbol of Quality

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y. *ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927*

'SENSITIVE RESEARCH' Field Engineers All Over The World!

NEW ENGLAND & MID-ATLANTIC STATES

New York (Met. Area), New Jersey (N.)
SENSITIVE RESEARCH HOME OFFICE
New Rochelle, N. Y. BEverly 5-2300

New York (W.)
THE ROBERT F. LAMB CO.
Buffalo, N. Y. TR 6-3757

New York (Central Area)
J. F. WULFETANGE, JR.
DeWitt, N. Y. GI 6-3330

New England & New York (E.)
YEWELL ASSOCIATES, INC.
Burlington, Mass. BR 2-9000
Bridgeport, Conn. FO 6-3456
Poughkeepsie, N. Y. GR 1-3456

Penna. (E.), New Jersey (S.)
I. E. ROBINSON CO.
W. Conshohocken, Pa. CH 8-1600 (Phila.)
Camp Hill, Pa. RE 7-6791
Asbury Park, N. J. KE 1-3150

Penna. (W.)
S. STERLING CO.
Pittsburgh, Pa. TU 4-5515

SO. ATLANTIC & SO. CENTRAL STATES

Washington, D. C.; Maryland, Dela., Virginia (N).
HORMAN ASSOCIATES, INC.
Rockville, Md. HA 7-7560
Baltimore, Md. MO 4-4400

Virginia (S.); No. & So. Carolina
JAMES L. HIGHSMITH & CO.
Charlotte, No. Carolina FR 7-2546
Richmond, Va. EL 9-1411

West Virginia
S. STERLING CO.
Pittsburgh, Pa. TU 4-5515

Ga., Kentucky, Tenn., Ala., Fla., Miss.
BIVINS & CALDWELL, INC.
Atlanta, Ga. CE 3-7522
Huntsville, Ala. 534-5733
Orlando, Fla. CH 1-1091

Texas, Oklahoma, Louisiana, Arkansas
ARNOLD BARNES COMPANY
Dallas, Texas LA 6-8735
Tulsa, Okla. NA 7-1515

MID-WESTERN STATES

Michigan, Ohio
S. STERLING CO.
Detroit, Mich. BR 3-2900
Cleveland, Ohio HI 2-8080
Dayton, Ohio AX 8-7573

Indiana
LAW INSTRUMENT CO.
Angola, Ind. 217
Indianapolis, Ind. ST 7-0009

Illinois (N.), & Wisconsin (S.)
SAFFRO & ASSOCIATES
Chicago, Ill. JU 8-0905

Illinois (S.), Missouri, Kansas
HARRIS-HANSON CO.
St. Louis, Mo. MI 7-4350
Kansas City, Mo. HI 4-9494

Minnesota, Iowa, Nebraska, No. & So. Dakota, Wisconsin (N.)
THE HEIMANN CO.
Minneapolis, Minn. FE 2-5457

PACIFIC and MT. STATES — ALASKA and HAWAII

California, Arizona, Nevada
McCARTHY ASSOCIATES, INC.
Pasadena, Calif. MU 1-7411
Menlo Park, Calif. DA 6-7937
San Diego, Calif. BR 4-1100

Washington, Oregon, Idaho, Montana (W.), Hawaii & Alaska
ARVA, INC.
Seattle, Washington MA 2-0177
Portland, Oregon CA 2-7337
Honolulu, Hawaii 506-096

Colorado, Utah, Wyoming, Montana (E.)
LAHANA & COMPANY
Denver, Colorado PE 3-3791
Salt Lake City, Utah HU 6-8166

New Mexico
GENE FRENCH COMPANY
Albuquerque, N. Mexico AM 8-2478

PRELIMINARY SPECIFICATIONS

Symbol of Quality

A SENSITIVE RESEARCH COMMANDER INSTRUMENT

AC/DC-DC CALIBRATION CONSOLE

MODEL **LTC-1**

The Model LTC-1 is the second edition in a series of test consoles designed for the certification or measurement of AC/DC voltage and current to an accuracy of ±.05% of reading from DC to 25 kc. Its performance characteristics are similar to those of the Model LTC excepting that it is furnished in an aluminum shielded case and is equipped with a 100% automatic overload protection system for all voltage inputs. (Thermocouple burnout protection only. Under certain conditions, overloads of more than 300% could impair reversal characteristics). The configuration, physical dimensions, and general appearance of the LTC-1 offer the user another choice in his selection of a calibration console that will best meet the demands of his application and blend in with the decor of his existing laboratory equipment.

The LTC-1 is fundamentally a Hermach type transfer standard with some important modifications to increase accuracy and ease of operation. It contains a separate, fast, DC calibrator so that DC measurements do not have to be made by the thermocouple transfer method.

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

The self contained light beam galvanometer is the "COMMANDER Type 9411. Sensitivity is such that a deflection of 1 mm division amounts to an AC/DC transfer error of approximately .015%. The galvanometer is oil damped and hence not subject to disturbance from normal vibration. A knob on the front panel allows for the zero adjustment of the light spot over the entire length of the scale.

All ranges are switch controlled. Each range position is an individually calibrated point and consequently accuracy is in terms of reading rather than of full scale. The inclusion of an Incremeter*for a "% Error" readout gives the user the option of either setting an instrument under test at a particular scale value and reading the Incremeter, or nulling the Incremeter and reading the deviation on the scale of the instrument. However, it is an obvious advantage to read the Incremeter since it has an effective resolution of 10x to 20x that of most electrical indicating instruments. The "% Error" indicator is automatically protected against overloads of 5000%.

The Incremeter is constantly compared to an internal ± .01% Zener diode reference source. Accuracy of the reference is unaffected by variations in line voltage of 95 v to 135 v or changes in temperature of 20°C to 30°C. It is recommended that the reference be checked monthly although stability data compiled to the present time indicates it is capable of maintaining its output accurately for periods of one year or more. External binding posts are included for recertifying against a standard cell. Facilities are provided for a simple screw adjustment of the reference (± .2% maximum possible variation) if a modification of the output is found necessary.

Thermocouples are of the uncalibrated type, and replacement can be made from the front of the panel. Coarse and fine DC controls are provided for use with external power sources (not supplied). All AC/DC transfer controls are included. It is recommended that the Model LT-PS-1 be used as a variable frequency AC power source that will operate within the performance capabilities of the console (See Model LT-PS-1 specification sheet).

The Model LTC series are the only calibration consoles to offer all the advantages listed below. It is important to note that the accuracy as stated is the actual total accuracy obtainable, since no accessory measuring equipment such as potentiometers, volt boxes, etc. (which pyramid this specification) is necessary.

---

*Ref: Sensitive Research ELECTRICAL MEASUREMENTS
Volume 27, Number 11, dated November, 1958

For a further, more complete, discussion of the basic design and the internal circuitry of the console, the reader is referred to NBS publication, "A Wide-Range Volt-Ampere Converter for Current and Voltage Measurements" by F. L. Hermach and E. S. Williams, and Sensitive Research ELECTRICAL MEASUREMENTS Vol. 28, No. 3, March, 1960.

ADDITIONAL SPECIFICATIONS

ACCURACY: ± .05% of reading

AC/DC RANGES: 2 ma - 11.10 amperes in steps of 1 ma;
.5 v - 1110 v in steps of .1 v

DC RANGES: 1 ma - 11.10 amperes in steps of 1 ma;
.5 v - 1110 v in steps of .1 v

SENSITIVITY: AC/DC, 100 ohms per volt; DC, 1000 ohms per volt
All current ranges have a 2 v potential drop.

FREQUENCY RANGE: .5-99 volts, DC-25,000 cycles; 100-199 volts, DC-20,000 cycles; 200-399 volts, DC-12,500 cycles; 400-1110 volts, DC-2,500 cycles; .002-.499 ampere, DC-20,000 cycles; .500-1.99 amperes, DC-10 kc; 2.00-11.10 amperes, DC-5 kc.
Lowest practical frequency for full accuracy is 10 cps.

READOUT: Directly in "%Error" (±5%-0-5%) or in actual values.

POWER REQUIRED: 115 v 60 cycle source; two 6 volt storage batteries
(Not Supplied) for DC current; a regulated 1000 v DC power supply.

Model LT-PS-1 is available on separate order. It is an AC source capable of supplying up to 1000 volts or 10 amperes (50 va total), over a variable frequency range (20 cps - 20 kc), with low distortion (.1%-.25% max.) and high short term amplitude stability (± .01%).

SIZE:	36" left to right x 28" high x 20" deep
WEIGHT:	125 lbs.
SHIPPING WEIGHT:	175 lbs.
PRICE:	$5,560.00
TERMS:	Net 30 days f.o.b., New Rochelle, New York

The calibration of all Sensitive Research instruments is directly traceable to the National Bureau of Standards in Washington, D.C. or Boulder, Colorado. Unless otherwise stated, warranty is for a period of one year.

Printed in U.S.A.

Prices and specifications subject to change without notice.

SENSITIVE RESEARCH

Introduces . . .

NEW DESIGNS

IN

EDGEWISE PANEL CASES

* * *

Our Type EW and Model JW edgewise panel cases have recently been redesigned so as to include front zero shifters. (Please see dimension sheet dated May 23, 1961, enclosed.) As there are differences in dimensions between these and the previous edgewise cases, you will note that the new cases are designated by the suffix "A". We are pleased to be able to offer you a superior instrument at no difference in cost.

It is our policy to supply the new deep or shallow EW-5A, EW-7A, or JW-4A cases on orders for edgewise panel mounting instruments received after 5/23/61. If, however, interchangeability with existing instruments will be affected, the former EW and JW cases will always be available.

If you have any questions regarding these new-style cases, please do not hesitate to contact this office or your Sensitive Research area representative.

New catalog insert enclosed.

FEB - 1 1962 PM

SENSITIVE
RESEARCH

SENSITIVE RESEARCH INSTRUMENT CORP.

Manufacturers of precise electrical instruments for 33 years. Through experience and dependability the name of Sensitive Research has become a hallmark in industry. The 0.05% accuracy of their Laboratory Standard Meters is an example of why you should look to Sensitive when you need the ultimate in precision.

AC-DC LABORATORY STANDARD CALIBRATION CONSOLE
AC, DC AND MAGNETIC TESTING SETS FOR
  ALTERNATING CURRENT, DIRECT CURRENT, AND
  MAGNETIC MEASUREMENTS
AMMETERS, MILLIAMMETERS AND MICROAMMETERS
AUDIO FREQUENCY VOLTMETERS AND CURRENT METERS
CONTACT METERS • CURRENT PRODUCT METERS
DC VOLTAGE STANDARD, .01% ACCURACY
DIFFERENTIAL GALVANOMETERS
DIRECT READING FREQUENCY METERS
ELECTROSTATIC VOLTMETERS
FLUXMETERS • FLUX VOLTMETERS
FORM FACTOR METER
INCREMETER (Suppressed zero standards)
LABORATORY STANDARDS
MODEL SCAMA, SCALE DRAWING MACHINE
MUTUAL CONDUCTANCE METERS
PANEL INSTRUMENTS
PEAK READING OR CREST VOLTMETERS
POLYRANGERS
PORTABLE DC AND AC REFERENCE STANDARDS
POTENTIOMETER VOLTMETERS
POWER FACTOR METER
RATIO METERS
RF VOLTMETERS AND CURRENT METERS
RF VOLTMETER CALIBRATOR
RUGGEDIZED REFERENCE STANDARDS
SELF-CHECKING LABORATORY STANDARDS
SHUNTS AND MULTIPLIERS
SPECIAL INSTRUMENTS
VACUUM AND AIR THERMOCOUPLES
VOLT-AMP-WATTMETERS • WATTMETERS
ZERO RESISTANCE METERS

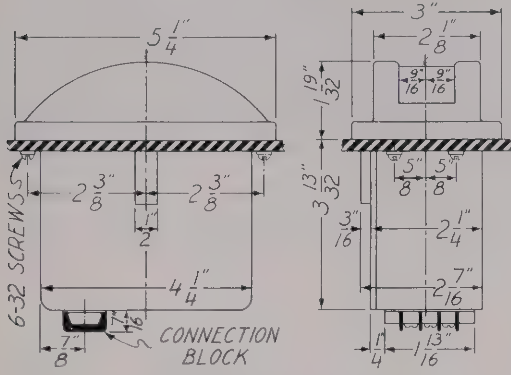
TERMS: Net 30 Days • F.O.B. Point: New Rochelle, N.Y. • Territory: Mich., Ohio, West. Pa., West Va.

Effective May 23, 1961

MOUNTING DIMENSIONS

For "Sensitive Research" Edgewise Panel Cases

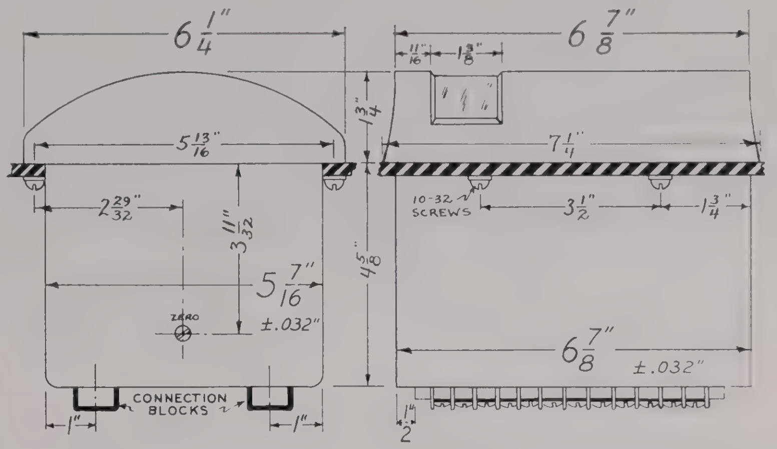
Practically all DC and Thermal instruments can be internally switch controlled for a maximum of 8 ranges.



5 1/4"
6-32 SCREWS
2 3/8"
2 3/8"
1/2
4 1/4"
7/16
7/8"
CONNECTION BLOCK
3"
2 1/8"
9/16
9/16
1 19/32"
3 13/32"
5/8
5/8
3/16"
2 1/4"
2 7/16"
1/4"
1 13/16"

TYPE JW-4A CASE

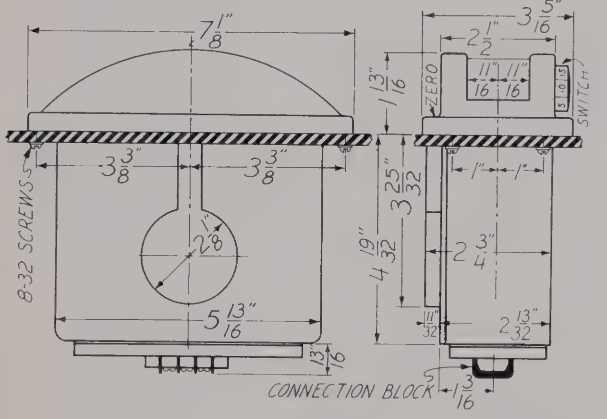
FOR MODELS JW, JDJW, JWG



6 1/4"
5 13/16"
2 29/32"
3 11/32"
5 7/16"
±.032"
ZERO
CONNECTION BLOCKS
1"
1"
1 3/4"
4 5/8"
6 7/8"
11/16"
1 3/8"
7 1/4"
10-32 SCREWS
3 1/2"
1 3/4"
6 7/8"
±.032"
1/2

TYPE PDWEW-5 OR PDLWEW-5 CASE

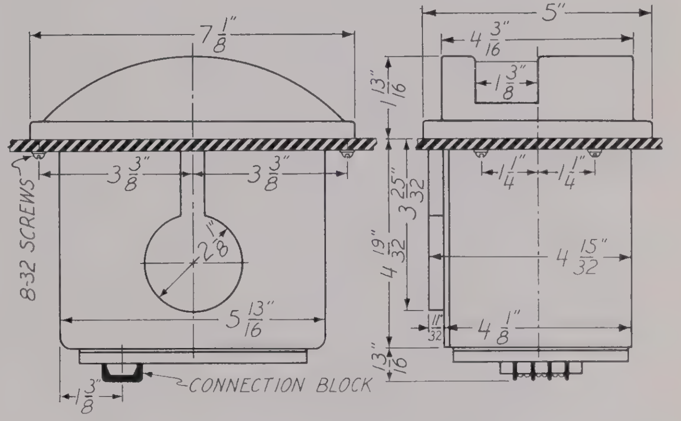
FOR MODELS PDW AND PDLW (3 phase wattmeters)



7 1/8"
8-32 SCREWS
3 3/8"
3 3/8"
2 1/8"
5 13/16"
13/16
CONNECTION BLOCK
1 3/16
3 5/16"
2 1/2"
11/16
11/16
ZERO
SWITCH
1 13/16"
3 25/32
4 19/32"
1"
1"
2 3/4"
11/32
2 13/32"

TYPE EW-5A SHALLOW CASE

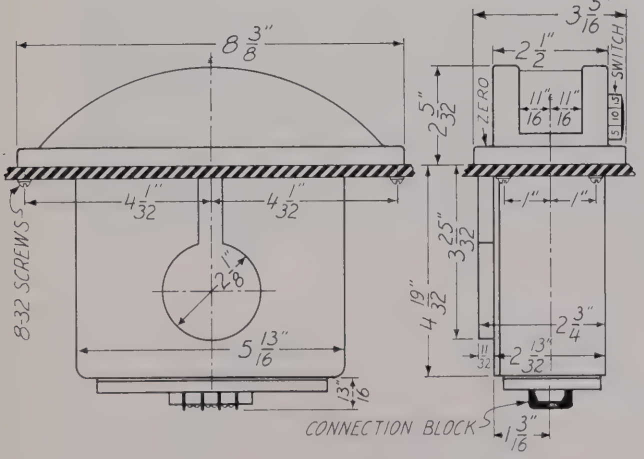
FOR MODELS S, C, A, HS, MI, FS, FM, SD, RA, AU, XT AND FLV



7 1/8"
8-32 SCREWS
3 3/8"
3 3/8"
2 1/8"
5 13/16"
1 3/8"
CONNECTION BLOCK
5"
4 3/16"
1 3/8"
1 13/16"
3 25/32"
4 19/32"
1 1/4"
1 1/4"
4 15/32"
11/32
4 1/8"
13/16"

TYPE EW-5A DEEP CASE

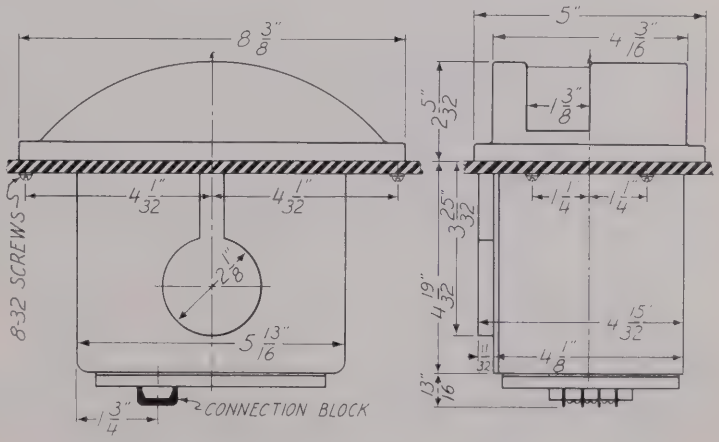
FOR MODELS D, DLW, DW, ESD, GM, DYSP, FRE, PF AND PPF



8 3/8"
8-32 SCREWS
4 1/32"
4 1/32"
2 1/8"
5 13/16"
13/16"
CONNECTION BLOCK
1 3/16"
3 5/16"
2 1/2"
SWITCH
ZERO
11/16
11/16
2 5/32"
3 25/32"
4 19/32"
1"
1"
2 3/4"
11/32
2 13/32"

TYPE EW-7A SHALLOW CASE

FOR MODELS S, C, FLV, MI, FS, FM, A, RF AND RA



8 3/8"
8-32 SCREWS
4 1/32"
4 1/32"
2 1/8"
5 13/16"
1 3/4"
CONNECTION BLOCK
5"
4 3/16"
1 3/8"
2 5/32"
1 1/4"
1 1/4"
3 25/32"
4 19/32"
4 15/32"
11/32
4 1/8"
13/16"

TYPE EW-7A DEEP CASE

FOR MODELS DW, D, DYSP, ESD, FRE, PF AND PPF

Reprint #1 of page 215, 5th Printing DC Section, Catalog #70. Issued with larger numerals May 23, 1961, to facilitate reading of dimensions.

(Please see reverse side)

GENERAL INFORMATION

NOTE 1: Edgewise panel cases are NORMALLY furnished with terminal strips. However, some instruments, such as — *most electrostatic voltmeters, high current and other special types,* demand binding posts and are furnished that way.

NOTE 2: Front zero adjusters are standard on the JW-4A, and the deep and shallow EW-5A and EW-7A cases.

NOTE 3: The same type of switch is utilized on the EW-5A and EW-7A deep cases as is illustrated in the dimensional drawings of the shallow cases.

NOTE 4: Instruments in Type JW-4A cases cannot be internally switch controlled.

"SENSITIVE RESEARCH" FIELD ENGINEERS

All Over The World

New England & Mid-Atlantic States

New York (Met. Area), New Jersey (N.)
SENSITIVE RESEARCH HOME OFFICE
New Rochelle, N. Y. BEverly 5-2300

New York (W.)
THE ROBERT F. LAMB CO.
Buffalo, N. Y. TR 6-3757

New York (Central Area)
J. F. WULFETANGE, JR.
DeWitt, N. Y. GI 6-3330

New England & New York (E.)
YEWELL ASSOCIATES, INC.
Burlington, Mass. BR 2-9000
Bridgeport, Conn. FO 6-3456
Poughkeepsie, N. Y. GR 1-3456

Penna. (E.), New Jersey (S.)
I. E. ROBINSON CO.
W. Conshohocken, Pa. CH 8-1600 (Phila.)
Camp Hill, Pa. RE 7-6791
Asbury Park, N. J. KE 1-3150

Penna. (W.)
S. STERLING CO.
Pittsburgh, Pa. TU 4-5515

So. Atlantic & So. Central States

Washington, D. C.; Maryland, Dela., Virginia (N.)
HORMAN ASSOCIATES, INC.
Rockville, Md. HA 7-7560
Baltimore, Md. MO 4-4400

Virginia (S.); No. & So. Carolina
JAMES L. HIGHSMITH & CO.
Charlotte, No. Carolina FR 7-2546
Richmond, Va. EL 9-1411

West Virginia
S. STERLING CO.
Pittsburgh, Pa. TU 4-5515

Ga., Kentucky, Tenn., Ala., Fla., Miss.
BIVINS & CALDWELL, INC.
Atlanta, Ga. 233-1141
Huntsville, Ala. 534-5733
Orlando, Fla. CH 1-1091

Texas, Oklahoma, Louisiana, Arkansas
ARNOLD BARNES COMPANY
Dallas, Texas LA 6-8735
Tulsa, Okla. NE 7-1515

Mid-Western States

Michigan, Ohio
S. STERLING CO.
Detroit, Mich. BR 3-2900
Cleveland, Ohio HI 2-8080
Dayton, Ohio AX 8-7573

Indiana
LAW INSTRUMENT CO.
Angola, Ind. 217
Indianapolis, Ind. ST 7-0009

Illinois (N.), & Wisconsin (S.)
SAFFRO & ASSOCIATES
Chicago, Ill. JU 8-0905

Illinois (S.), Missouri, Kansas
HARRIS-HANSON CO.
St. Louis, Mo. MI 7-4350
Kansas City, Mo. HI 4-9494

Minnesota, Iowa, Nebraska, No. & So. Dakota, Wisconsin (N.)
THE HEIMANN CO.
Minneapolis, Minn. FE 2-5457

Pacific and Mt. States — Alaska and Hawaii

California, Arizona, Nevada
McCARTHY ASSOCIATES, INC.
Pasadena, Calif. MU 1-7411
Menlo Park, Calif. DA 6-7937
San Diego, Calif. BR 4-1100

Washington, Oregon, Idaho, Montana (W.) Hawaii & Alaska
ARVA, INC.
Seattle, Washington MA 2-0177
Portland, Oregon CA 2-7337
Anchorage, Alaska BR 2-6731
Honolulu, Hawaii 269-781

Colorado, Utah, Wyoming, Montana (E.)
LAHANA & COMPANY
Denver, Colorado PE 3-3791
Salt Lake City, Utah HU 6-8166

New Mexico
GENE FRENCH COMPANY
Albuquerque, N. Mexico AM 8-2478

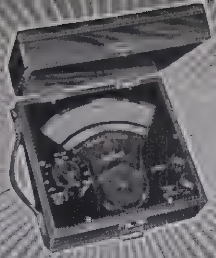
Canada & Export

Canada (E.)
MEL SALES LTD.
Toronto, Ontario HU 1-0231
Montreal, Quebec NA 7-4313

Canada (W.)
ARVA, INC.
Vancouver, B. C. RE 6-6377

Export
AD. AURIEMA, INC.
New York, N. Y. BO 9-7750

Printed in U.S.A

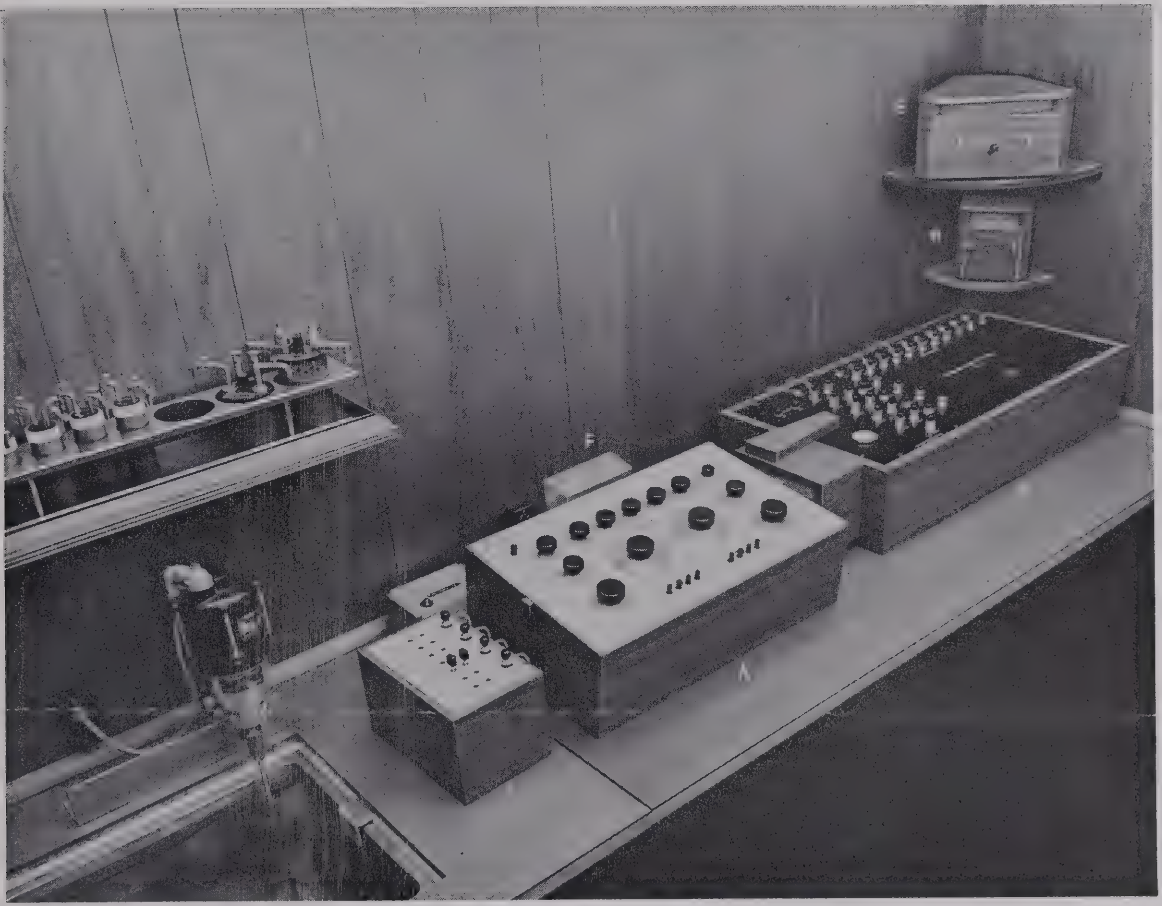


Electrical MEASUREMENTS

VOLUME 29 SEPTEMBER, 1962 VOLUME 9

SEP 2

"OUR"
IDEAL SMALL D.C. STANDARDS LABORATORY



THIS IS PART OF THE LABORATORY DESCRIBED HEREIN

The last few years have seen an increasing number of organizations faced with the problem of setting up an Electrical Standards Laboratory. This is a natural outcome of the general trend to the use of electrical and electronic methods for solving an infinite variety of problems. In addition, our "space age" technology is demanding ever and ever greater levels of accuracies for routine measurements.

The increasing complexity of electrical circuits leads to the products of many manufacturers being pyramided to form one complex pyramid. These factors make it imperative that a volt or an ohm, measured in the plant of manufacturers A, B, C and so on to X, are mutually compatible.

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

Symbol of Quality

....TO MEASURE IS TO KNOW....

An increasing number of organizations have been coming to us with the question, "What do we need in the way of equipment and personnel, to provide a satisfactory standards program for our operation?" There is, of course, no single answer to a question such as this. However, to answer as large a percentage of the general inquiries as possible we are devoting this issue of ELECTRICAL MEASUREMENTS to a detailed discussion of setting up a hypothetical small D.C. standards laboratory.

We are making this hypothetical laboratory a small one because, if you have problems enough and money enough to justify a large standards laboratory, you probably also have technically qualified help to establish it. If not, then your first problem can be very simply stated, "Get such a man." The more common situation is a small or medium sized organization, where management finally, and usually reluctantly, decides that money and time must be expended to establish a standards operation. Mr. Smith, Mr. Brown, and Mr. Jones are promptly assigned to the project and after discussing it among themselves find that none of them has any background or experience in electrical standards. To these three gentlemen the following is dedicated.

The first step in establishing a standards laboratory, obviously has to be a survey of the needs and requirements. What ranges of voltage current, resistance, frequencies, and powers are required to be standardized and secondly, to what accuracy do these values need to be standardized? Look at the second question first. If the answer to the required accuracy in the plant turns out to be that no real requirement for measurement accuracies beyond ½ percent or thereabouts are needed in the routine operation, then the problem becomes relatively simple.

If the answer is "requirements of ¼ percent and better are needed in routine factory measurements," then direct reading indicating instruments are readily available in practically all ranges with accuracies of 1/10 percent and ¼ percent. Purchases of a satisfactory range of such reference standard direct indicating instruments literally side-steps what is usually considered standards laboratory operation. In effect it shifts this entirely to the instrument manufacurer's own laboraory. These direct indicating instruments, by having an outside recertification done regularly by either the manufacturer or other recognized standards laboratories, will be ample to assure conformance of factory operations to ½ percent or better.

A perusal of our SENSITIVE RESEARCH Catalogue will show a most satisfactory range of direct reading standards for use where such accuracies are tolerable. Our Models B, L, and LW provide a wide range of voltage, current, and power for both D.C. in the Model B and LW and for A.C. with the L and LW. All of these instruments have basic .1 percent accuracies for use where a reference standard of ¼ percent accuracy is adequate. Our Model C Voltmeters and current instruments for D.C. and the Model D Dynamometers for A.C. measurements of voltage and current are extremely satisfactory instruments with excellent long term stability. For power measurements, our Model DW Wattmeters are in the same accuracy class.

For the small laboratory where even lower accuracies are satisfactory, special attention should be given to the Model S as a D.C. ½ percent instrument with high sensitivity, as well as good accuracy.

For the ultimate in economy, without too great a sacrifice in other characteristics, our UNIVERSITY series of instruments should be considered. In all cases, instruments should be not only accurate but have long scales, well marked, with a mirror for parallax elimination to give adequate resolution as well as accuracy. SENSITIVE RESEARCH is justifiably proud of the hand calibrated scale characteristics and long term stability of our moderately priced instuments.

Management should provide a goodly number of such instruments, with careful storage and handling, a fool proof system for assuring the recertifying of the instruments, and a satisfactory level of personnel to use these instruments to check the working instruments in the plant. Do this and you will have an acceptable standards operation for this level of accuracy.

Ordinarily the term "Standards Laboratory" refers to an electrical certifying organization where accuracies of 1/10 percent or better are expected in the certification of other instruments. To operate in this area, an entirely different basic concept is required. To hold these accuracies some form of long term stability, high accuracy standards are required. Of necessity, these standards MUST originate in an unbroken chain from the National Bureau of Standards.

The magic word "traceability" requires that the links in this chain back to the Bureau be known and documented. It does NOT require that measurements be directly and immediately referred to NBS by means of a single link. The chain can have any number of links or steps between NBS and the measurement being made, providing those steps are satisfactorily documented and reasonable additional tolerances are allowed for each additional step taken. The exact methods of documentation will vary for all of the different types of measurements required. Only very recently have attempts been made to specify the exact steps required in each individual case. It is, however, agreed by all organizations demanding such certifications that the steps be technically sound, that the tolerance must be reasonable and the entire proceedings documented.

Electrical measurements as such, stem from a hierarchy of standards the basis of which is the fundamental D.C. value of the ohm, the volt and the ampere. Elaborate procedures undertaken by various National Standardizing Laboratories have resulted in accurate and maintainable values for the volt and for the ohm, in terms of absolute measurements. By definition, measurements which can be referred directly to length, mass and time, are the basic fundamental units of measurements.

The ampere is basically a transient phenomenon and as such is incapable of being maintained as a satisfactory standard. Hence, it is derived from the two remaining fundamental units; the volt and ohm. The National and legal value of the volt is maintained in the form of a group of saturated cells with an exceptionally long history and maintained in a carefully temperature-controlled oil bath by the National Bureau of Standards. The value of the National Standards is known in terms of absolute values to within some 2 or 3 parts per million.

However, this National Standard is stable and reproducible to small fractions of a micro-volt and comparisons to the National Standard can readily be made to better than tenths of a micro-volt.

...INSTRUMENTS CERTIFY NEW KNOWLEDGE...

Any bank of saturated cells maintained in a carefully thermostated enclosure can be carefully taken to the National Bureau of Standards, compared to the National Standard and returned to your own Standards Laboratory. Including all the possible inaccuracies of comparison and long term stabilities of a standard cell enclosure, such as our SRIC Model 9152, a known value of voltage can then be maintained in your laboratory to within 1 or 2 parts per million. These values can then be relied upon for periods of a year or more between NBS recertifications.

Similarly, a value of resistance in the form of a Thomas or similar type 1 ohm resistances can be compared to the National Standard bank of resistances at NBS and removed to your own laboratory and maintained with an uncertainty in the order of 1 or 2 parts per million. This expected accuracy will be attainable only under relatively ideal conditions and after at least two certifications by NBS to establish a lack of drift in the individual units involved.

It is possible then to establish independent laboratories, values of voltage and resistance with accuracies no worse than a few parts per million. Having a voltage in the order of 1.0185 volts in your laboratory of KNOWN accuracy and a resistor of approximately 1 ohm of KNOWN value will actually allow you to build a complete D.C. standards system, ENTIRELY ON YOUR OWN.

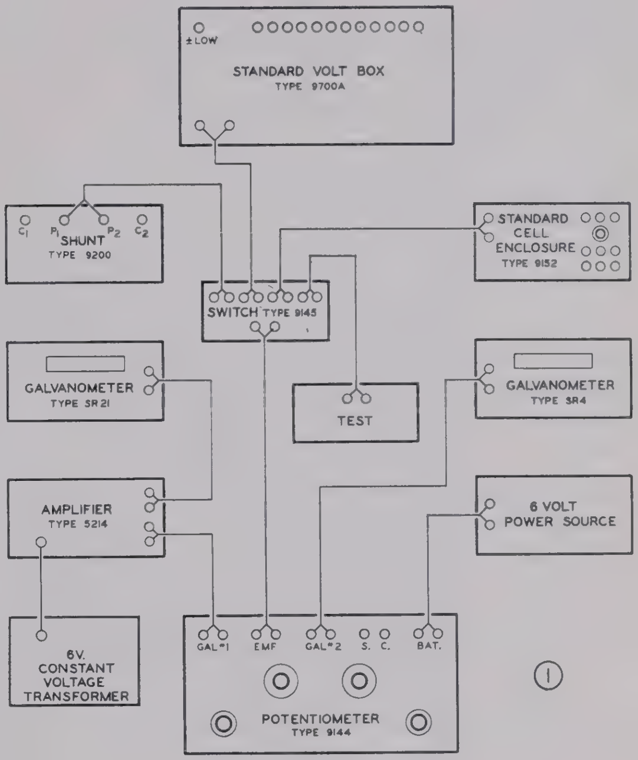
This building of one's own system in their own laboratory based on only these two values is a most IMPORTANT CONCEPT. All other measurements of voltage, resistance or current, can be derived from these values by methods, which are inherently self-checking and provable and do not require reference to any outside facilities whatsoever!

In the case of a resistance, a second resistance can be compared to the known resistance and its error accurately determined by means of many different methods to a degree of accuracy comparable with that which the original resistance was certified. Having checked resistance B against A, you can go further and check C against B, D against C and so on, until you have a group of resistances of similar and equally accurate known values.

If satisfactory comparison methods are used, having known values of A, B, C and D, then this group of resistances can be connected as a ratio device and equally well known ratios can be determined of 1 to 2, 1 to 3, 1 to 4 and so forth. These ratios can then be used to extrapolate, either up or down, for ratios of either resistance or voltage and these ratio methods can be used to extend the voltages DOWN into the micro-volt range and UP into thousands of volts, with each individual step being self-checking and selfproving.

An example of such a device is the potentiometer. A potentiometer consists essentially of a group of resistances, the ratios of which are accurately known and their accuracy of ratio can be selfproved. Many potentiometers, such as the SRIC Model 9144, and others of our Commander Line, make this self proving check convenient by the inclusion of the necessary connections and switching built into the potentiometer itself. However, with sufficient care and patience ANY potentiometer can have its ratio accuracy proved by self-check methods.

Similarly, to extend voltage ranges above the standard cell range, a potentiometer can be used with a volt box. Once again, the volt box is a resistive ratio device and as such is completely self-checkable. The SRIC Model 9700 and 9700A standard volt boxes are excellent examples of highly accurate volt boxes made convenient for self-checking procedures. National Bureau of Standards research paper 1419 describes in great detail the methods of providing these self-check certifications.



The above block diagram shows a very satisfactory standards set-up for maintaining and certifying D.C. instruments. As the standard of voltage, a SRIC Model 9152 standard cell enclosure is used. As a standard of resistance, a type 9200 shunt is shown. This is slightly lower in terms of absolute accuracy than would be an individual Thomas type 1 ohm resistance; but its extremely wide range and convenience justifies its inclusion in this suggested set-up.

These two units are connected through a type 9145 low thermal switch to the input of a Model 9144 potentiometer. The potentiometer is the precision read-out instrument for all of the various measurements to be made with this set-up. It must be provided with an extremely stable six volt power source, which ordinarily consists of a storage battery, which has been charged and connected to the instrument and allowed to stabilize for several days.

The detector in the EMF circuit is shown as SRIC Model 5214 galvanometer amplifier and an SR 21 galvanometer. This provides the ULTIMATE in sensitivity and allows the full fractional part per million resoluton of the potentometer to be used in these measurements. ("You can't read it, if you can't see it.")

This galvanometer amplifier combination will allow single micro-volt differences to be expanded to approximately FULL SCALE on the galvanometer, and thus, the galvanometer resolution is not a limiting factor on any measurements that may be made. For convenience, a standard volt box, the standard cell enclosure, the 9200 shunt and a separate pair of test binding posts for other measurements, are all connected to the input of the potentiometer through the 9145 switch. A second galvanometer, the type SR 4, is shown connected for use with the two internal standard cells provided in the 9144. This is convenient for providing a short term reference without referring back to the 9152, except for the most accurate of measurements.

In this Standard Laboratory, it would be necessary once a year to provide recertification of the 9152 and of the 9200 to maintain satisfactory documentation of the standards operation. The 9144 can be SELF CERTIFIED readily to within an accuracy of fractional parts per million.

In a similar manner, the 9700 A voltbox can be SELF CERTIFIED to within fractional parts per million. This set-up provides the basis of a complete satisfactory system of D.C. measurements in the range from a micro-volt or two, up through 1500 volts and for currents of fractional microamperes, up through 15 amperes.

The basic system required here is the same regardless of the accuracies, which may be required for your own standard operation. If accuracies of a few parts per million are not required, this same system can be operated at much lower levels by using potentiometers with inherently lower accuracies with lower accuracy volt box and shunts and with the saturated standard cell enclosure replaced possibly by a single unsaturated cell.

Under these conditions galvanometers of markedly lower sensitivities can be satisfactorily used. The overall accuracies, or to be more correct, the overall inaccuracy must not add up to greater than the allowed inaccuracies of your own certifications. The basic system is here, you require from some external laboratory a KNOWN voltage standard of a suitable accuracy. You require from an external laboratory a KNOWN resistance standard of suitable accuracy. You require the necessary extrapolation equipment, such as; potentiometer and volt box, which must be of such construction and design as to be stable and reproducible to the accuracies required. You require null detectors with sufficient sensitivity to detect the errors, which may be expected and you require satisfactory D.C. power sources with STABILITIES in the order of the accuracies required.

On page one we show our own D.C. standards laboratory, which contains all the equipment described above. Also shown is a constant temperature agitated oil bath in which are immerged our standard resistances when used for the most precise measurements. Details of this bath and complete test circuitry are available for purchases of these standards.

LIST OF EQUIPMENT SHOWN IN PHOTOGRAPH

A.	Commander Type 9144 Dauphinee Potentiometer (4 dial—6 figure) 0 to 2.101010 volts in .1 micro-volt steps—stable to better than 1.5 ppm per year	$5,934.00
B.	Commander Type 9700A Volt Ratio Box accuracy ±.001% 25 ranges from .15 volt to 1500 volts—stability ±10 ppm or better per year	$4,456.00
C.	Commander Type 9200 Multirange Standard Resistance (4 terminal resistances) 7 ranges .01 ohm to 10,000 ohms accuracy ±.01%	$ 423.00
D.	Commander Type 9145 Low Thermal Selector Switch (4 DPST sections) (thermal EMF's less than .01 microvolt) (NOT SHOWN)	$ 343.00
E.	Commander Type SR-21 Secondary Galvanometer sensitivity up to 350,000 millimeters per microampere when used with our Type 5214 Amplifier	$ 283.00
F.	Commander Type 5214 Photocell Galvanometer Amplifier (liquid filled to reduce effects of any external mechanical vibration. A 6 volt-15 watt constant voltage transformer is required for the amplifier lamp).	$ 805.00
G.	Commander Type 9152 Constant Temperature Standard Cell Enclosure (contains 4 Type 4305 Saturated Cells — maximum variation ±.01°C. (NOT SHOWN)	$ 979.00
H.	Commander Type 4500/SR-4 Galvanometer Resistance 50 ohms	$ 277.00
I.	6 volt Power Source Low Discharge Type Storage Battery (NOT SHOWN)	

The above equipment described in detail in literature available to you for the asking. We have a 5 year warranty on Potentiometers, Volt Ratio Boxes and Standard Resistances and one year on our portable indicating instruments.

◆

For over 29 years we have published this company bulletin "ELECTRICAL MEASUREMENTS." In it we describe new instruments and measurement techniques. It is sent without cost to interested persons. If you have not been receiving this publication, please advise "SENSITIVE RESEARCH."

Printed in U.S.A.

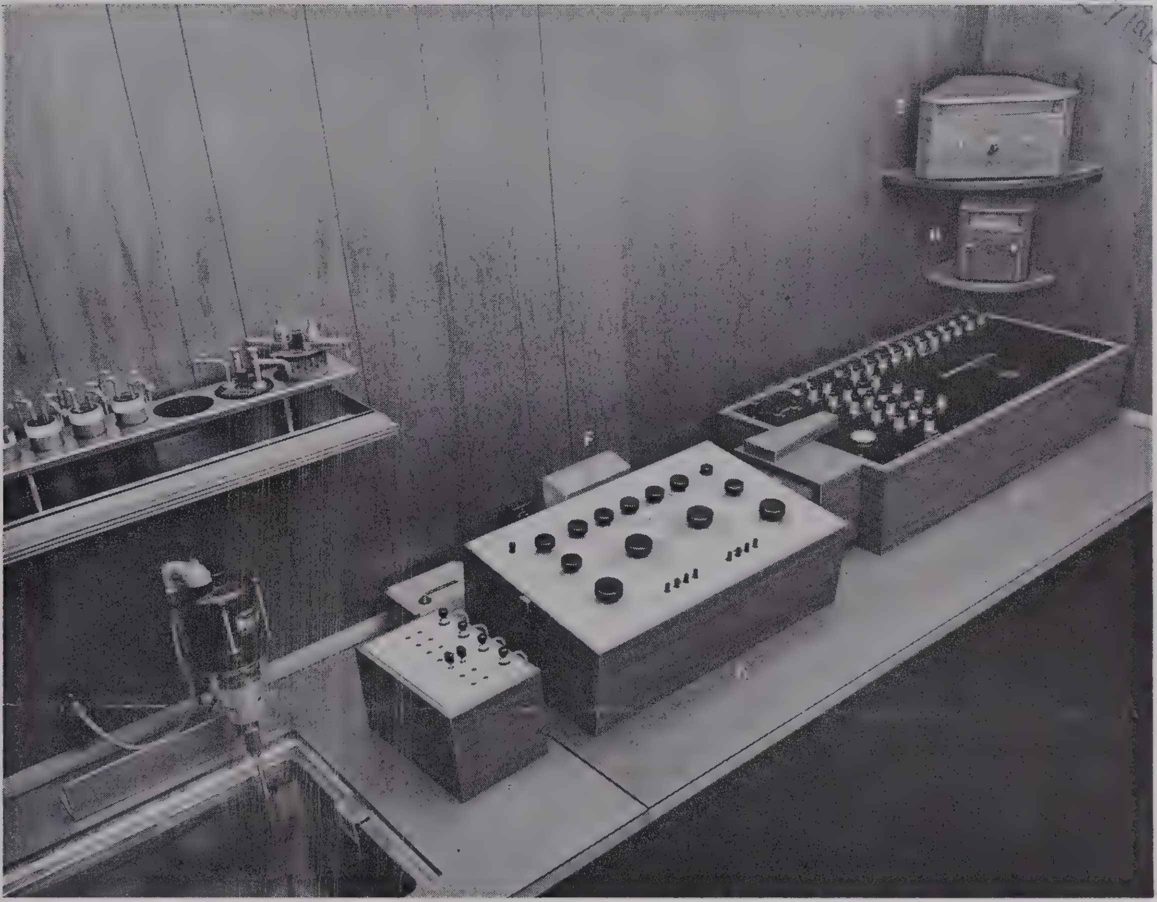
Prices and specification subject
to change without notice.

Electrical
MEASUREMENTS

VOLUME 29 SEPTEMBER, 1962 VOLUME 9

OUR"

IDEAL SMALL D. C. STANDARDS LABORATORY



THIS IS PART OF THE LABORATORY DESCRIBED HEREIN

The last few years have seen an increasing number of organizations faced with the problem of setting up an Electrical Standards Laboratory. This is a natural outcome of the general trend to the use of electrical and electronic methods for solving an infinite variety of problems. In addition, our "space age" technology is demanding ever and ever greater levels of accuracies for routine measurements.

The increasing complexity of electrical circuits leads to the products of many manufacturers being pyramided to form one complex pyramid. These factors make it imperative that a volt or an ohm, measured in the plant of manufacturers A, B, C and so on to X, are mutually compatible.

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

S

Symbol of Quality

An increasing number of organizations have been coming to us with the question, "What do we need in the way of equipment and personnel, to provide a satisfactory standards program for our operation?" There is, of course, no single answer to a question such as this. However, to answer as large a percentage of the general inquiries as possible we are devoting this issue of ELECTRICAL MEASUREMENTS to a detailed discussion of setting up a hypothetical small D.C. standards laboratory.

We are making this hypothetical laboratory a small one because, if you have problems enough and money enough to justify a large standards laboratory, you probably also have technically qualified help to establish it. If not, then your first problem can be very simply stated, "Get such a man." The more common situation is a small or medium sized organization, where management finally, and usually reluctantly, decides that money and time must be expended to establish a standards operation. Mr. Smith, Mr. Brown, and Mr. Jones are promptly assigned to the project and after discussing it among themselves find that none of them has any background or experience in electrical standards. To these three gentlemen the following is dedicated.

The first step in establishing a standards laboratory, obviously has to be a survey of the needs and requirements. What ranges of voltage current, resistance, frequencies, and powers are required to be standardized and secondly, to what accuracy do these values need to be standardized? Look at the second question first. If the answer to the required accuracy in the plant turns out to be that no real requirement for measurement accuracies beyond ½ percent or thereabouts are needed in the routine operation, then the problem becomes relatively simple.

If the answer is "requirements of ¼ percent and better are needed in routine factory measurements," then direct reading indicating instruments are readily available in practically all ranges with accuracies of 1/10 percent and ¼ percent. Purchases of a satisfactory range of such reference standard direct indicating instruments literally side-steps what is usually considered standards laboratory operation. In effect it shifts this entirely to the instrument manufacurer's own laboraory. These direct indicating instruments, by having an outside recertification done regularly by either the manufacturer or other recognized standards laboratories, will be ample to assure conformance of factory operations to ½ percent or better.

A perusal of our SENSITIVE RESEARCH Catalogue will show a most satisfactory range of direct reading standards for use where such accuracies are tolerable. Our Models B, L, and LW provide a wide range of voltage, current, and power for both D.C. in the Model B and LW and for A.C. with the L and LW. All of these instruments have basic .1 percent accuracies for use where a reference standard of ¼ percent accuracy is adequate. Our Model C Voltmeters and current instruments for D.C. and the Model D Dynamometers for A.C. measurements of voltage and current are extremely satisfactory instruments with excellent long term stability. For power measurements, our Model DW Wattmeters are in the same accuracy class.

For the small laboratory where even lower accuracies are satisfactory, special attention should be given to the Model S as a D.C. ½ percent instrument with high sensitivity, as well as good accuracy.

For the ultimate in economy, without too great a sacrifice in other characteristics, our UNIVERSITY series of instruments should be considered. In all cases, instruments should be not only accurate but have long scales, well marked, with a mirror for parallax elimination to give adequate resolution as well as accuracy. SENSITIVE RESEARCH is justifiably proud of the hand calibrated scale characteristics and long term stability of our moderately priced instuments.

Management should provide a goodly number of such instruments, with careful storage and handling, a fool proof system for assuring the recertifying of the instruments, and a satisfactory level of personnel to use these instruments to check the working instruments in the plant. Do this and you will have an acceptable standards operation for this level of accuracy.

Ordinarily the term "Standards Laboratory" refers to an electrical certifying organization where accuracies of 1/10 percent or better are expected in the certification of other instruments. To operate in this area, an entirely different basic concept is required. To hold these accuracies some form of long term stability, high accuracy standards are required. Of necessity, these standards MUST originate in an unbroken chain from the National Bureau of Standards.

The magic word "traceability" requires that the links in this chain back to the Bureau be known and documented. It does NOT require that measurements be directly and immediately referred to NBS by means of a single link. The chain can have any number of links or steps between NBS and the measurement being made, providing those steps are satisfactorily documented and reasonable additional tolerances are allowed for each additional step taken. The exact methods of documentation will vary for all of the different types of measurements required. Only very recently have attempts been made to specify the exact steps required in each individual case. It is, however, agreed by all organizations demanding such certifications that the steps be technically sound, that the tolerance must be reasonable and the entire proceedings documented.

Electrical measurements as such, stem from a hierarchy of standards the basis of which is the fundamental D.C. value of the ohm, the volt and the ampere. Elaborate procedures undertaken by various National Standardizing Laboratories have resulted in accurate and maintainable values for the volt and for the ohm, in terms of absolute measurements. By definition, measurements which can be referred directly to length, mass and time, are the basic fundamental units of measurements.

The ampere is basically a transient phenomenon and as such is incapable of being maintained as a satisfactory standard. Hence, it is derived from the two remaining fundamental units; the volt and ohm. The National and legal value of the volt is maintained in the form of a group of saturated cells with an exceptionally long history and maintained in a carefully temperature-controlled oil bath by the National Bureau of Standards. The value of the National Standards is known in terms of absolute values to within some 2 or 3 parts per million.

However, this National Standard is stable and reproducible to small fractions of a micro-volt and comparisons to the National Standard can readily be made to better than tenths of a microvolt.

...INSTRUMENTS CERTIFY NEW KNOWLEDGE...

Any bank of saturated cells maintained in a carefully thermostated enclosure can be carefully taken to the National Bureau of Standards, compared to the National Standard and returned to your own Standards Laboratory. Including all the possible inaccuracies of comparison and long term stabilities of a standard cell enclosure, such as our SRIC Model 9152, a known value of voltage can then be maintained in your laboratory to within 1 or 2 parts per million. These values can then be relied upon for periods of a year or more between NBS recertifications.

Similarly, a value of resistance in the form of a Thomas or similar type 1 ohm resistances can be compared to the National Standard bank of resistances at NBS and removed to your own laboratory and maintained with an uncertainty in the order of 1 or 2 parts per million. This expected accuracy will be attainable only under relatively ideal conditions and after at least two certifications by NBS to establish a lack of drift in the individual units involved.

It is possible then to establish independent laboratories, values of voltage and resistance with accuracies no worse than a few parts per million. Having a voltage in the order of 1.0185 volts in your laboratory of KNOWN accuracy and a resistor of approximately 1 ohm of KNOWN value will actually allow you to build a complete D.C. standards system, ENTIRELY ON YOUR OWN.

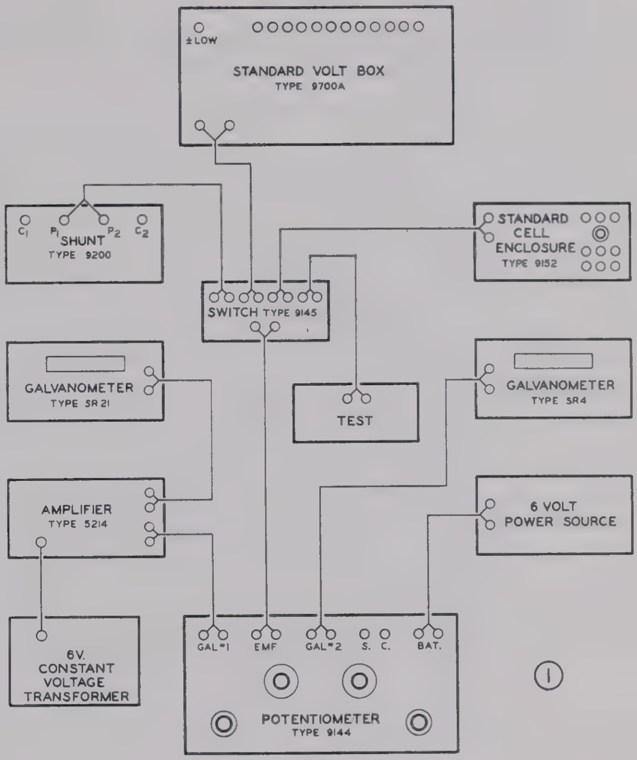
This building of one's own system in their own laboratory based on only these two values is a most IMPORTANT CONCEPT. All other measurements of voltage, resistance or current, can be derived from these values by methods, which are inherently self-checking and provable and do not require reference to any outside facilities whatsoever!

In the case of a resistance, a second resistance can be compared to the known resistance and its error accurately determined by means of many different methods to a degree of accuracy comparable with that which the original resistance was certified. Having checked resistance B against A, you can go further and check C against B, D against C and so on, until you have a group of resistances of similar and equally accurate known values.

If satisfactory comparison methods are used, having known values of A, B, C and D, then this group of resistances can be connected as a ratio device and equally well known ratios can be determined of 1 to 2, 1 to 3, 1 to 4 and so forth. These ratios can then be used to extrapolate, either up or down, for ratios of either resistance or voltage and these ratio methods can be used to extend the voltages DOWN into the micro-volt range and UP into thousands of volts, with each individual step being self-checking and selfproving.

An example of such a device is the potentiometer. A potentiometer consists essentially of a group of resistances, the ratios of which are accurately known and their accuracy of ratio can be selfproved. Many potentiometers, such as the SRIC Model 9144, and others of our Commander Line, make this self proving check convenient by the inclusion of the necessary connections and switching built into the potentiometer itself. However, with sufficient care and patience ANY potentiometer can have its ratio accuracy proved by self-check methods.

Similarly, to extend voltage ranges above the standard cell range, a potentiometer can be used with a volt box. Once again, the volt box is a resistive ratio device and as such is completely self-checkable. The SRIC Model 9700 and 9700A standard volt boxes are excellent examples of highly accurate volt boxes made convenient for self-checking procedures. National Bureau of Standards research paper 1419 describes in great detail the methods of providing these self-check certifications.



The above block diagram shows a very satisfactory standards set-up for maintaining and certifying D.C. instruments. As the standard of voltage, a SRIC Model 9152 standard cell enclosure is used. As a standard of resistance, a type 9200 shunt is shown. This is slightly lower in terms of absolute accuracy than would be an individual Thomas type 1 ohm resistance; but its extremely wide range and convenience justifies its inclusion in this suggested set-up.

These two units are connected through a type 9145 low thermal switch to the input of a Model 9144 potentiometer. The potentiometer is the precision read-out instrument for all of the various measurements to be made with this set-up. It must be provided with an extremely stable six volt power source, which ordinarily consists of a storage battery, which has been charged and connected to the instrument and allowed to stabilize for several days.

The detector in the EMF circuit is shown as SRIC Model 5214 galvanometer amplifier and an SR 21 galvanometer. This provides the ULTIMATE in sensitivity and allows the full fractional part per million resoluton of the potentometer to be used in these measurements. ("You can't read it, if you can't see it.")

This galvanometer amplifier combination will allow single micro-volt differences to be expanded to approximately FULL SCALE on the galvanometer, and thus, the galvanometer resolution is not a limiting factor on any measurements that may be made. For convenience, a standard volt box, the standard cell enclosure, the 9200 shunt and a separate pair of test binding posts for other measurements, are all connected to the input of the potentiometer through the 9145 switch. A second galvanometer, the type SR 4, is shown connected for use with the two internal standard cells provided in the 9144. This is convenient for providing a short term reference without referring back to the 9152, except for the most accurate of measurements.

In this Standard Laboratory, it would be necessary once a year to provide recertification of the 9152 and of the 9200 to maintain satisfactory documentation of the standards operation. The 9144 can be SELF CERTIFIED readily to within an accuracy of fractional parts per million.

In a similar manner, the 9700 A voltbox can be SELF CERTIFIED to within fractional parts per million. This set-up provides the basis of a complete satisfactory system of D.C. measurements in the range from a micro-volt or two, up through 1500 volts and for currents of fractional microamperes, up through 15 amperes.

The basic system required here is the same regardless of the accuracies, which may be required for your own standard operation. If accuracies of a few parts per million are not required, this same system can be operated at much lower levels by using potentiometers with inherently lower accuracies with lower accuracy volt box and shunts and with the saturated standard cell enclosure replaced possibly by a single unsaturated cell.

Under these conditions galvanometers of markedly lower sensitivities can be satisfactorily used. The overall accuracies, or to be more correct, the overall inaccuracy must not add up to greater than the allowed inaccuracies of your own certifications. The basic system is here, you require from some external laboratory a KNOWN voltage standard of a suitable accuracy. You require from an external laboratory a KNOWN resistance standard of suitable accuracy. You require the necessary extrapolation equipment, such as; potentiometer and volt box, which must be of such construction and design as to be stable and reproducible to the accuracies required. You require null detectors with sufficient sensitivity to detect the errors, which may be expected and you require satisfactory D.C. power sources with STABILITIES in the order of the accuracies required.

On page one we show our own D.C. standards laboratory, which contains all the equipment described above. Also shown, is a constant temperature agitated oil bath in which are immerged our standard resistances when used for the most precise measurements. Details of this bath and complete test circuitry are available for purchases of these standards.

LIST OF EQUIPMENT SHOWN IN PHOTOGRAPH

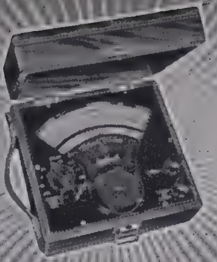
A.	Commander Type 9144 Dauphinee Potentiometer (4 dial—6 figure) 0 to 2.101010 volts in .1 micro-volt steps—stable to better than 1.5 ppm per year	$5,934.00
B.	Commander Type 9700A Volt Ratio Box accuracy ±.001% 25 ranges from .15 volt to 1500 volts—stability ±10 ppm or better per year	$4,456.00
C.	Commander Type 9200 Multirange Standard Resistance (4 terminal resistances) 7 ranges .01 ohm to 10,000 ohms accuracy ±.01%	$ 423.00
D.	Commander Type 9145 Low Thermal Selector Switch (4 DPST sections) (thermal EMF's less than .01 microvolt) (NOT SHOWN)	$ 343.00
E.	Commander Type SR-21 Secondary Galvanometer sensitivity up to 350,000 millimeters per microampere when used with our Type 5214 Amplifier	$ 283.00
F.	Commander Type 5214 Photocell Galvanometer Amplifier (liquid filled to reduce effects of any external mechanical vibration. A 6 volt-15 watt constant voltage transformer is required for the amplifier lamp).	$ 805.00
G.	Commander Type 9152 Constant Temperature Standard Cell Enclosure (contains 4 Type 4305 Saturated Cells — maximum variation ±.01°C. (NOT SHOWN)	$ 979.00
H.	Commander Type 4500/SR-4 Galvanometer Resistance 50 ohms	$ 277.00
I.	6 volt Power Source Low Discharge Type Storage Battery (NOT SHOWN)	

The above equipment described in detail in literature available to you for the asking. We have a 5 year warranty on Potentiometers, Volt Ratio Boxes and Standard Resistances and one year on our portable indicating instruments.

For over 29 years we have published this company bulletin "ELECTRICAL MEASUREMENTS." In it we describe new instruments and measurement techniques. It is sent without cost to interested persons. If you have not been receiving this publication, please advise "SENSITIVE RESEARCH."

Printed in U.S.A.

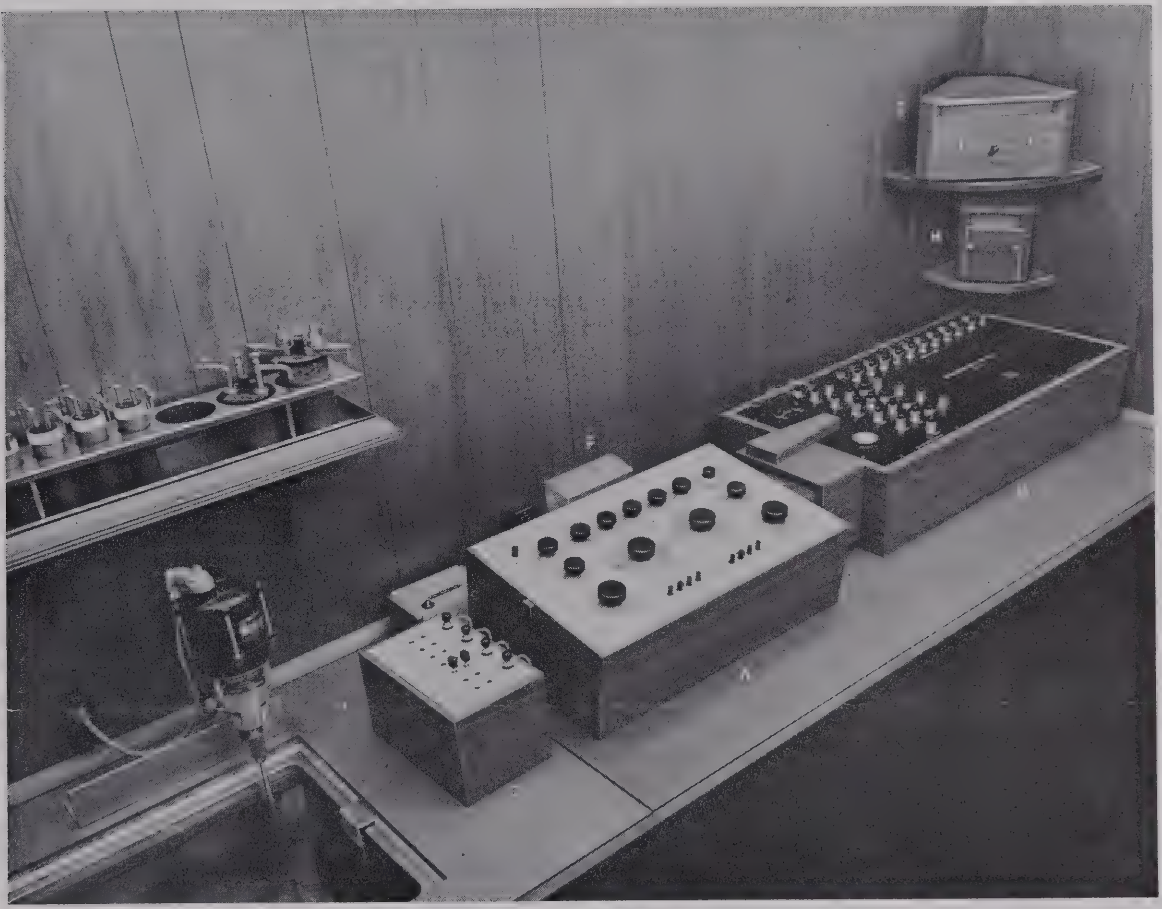
Prices and specification subject
to change without notice.



Electrical MEASUREMENTS

VOLUME 29 **SEPTEMBER, 1962** **VOLUME 9**

"OUR"
IDEAL SMALL D.C. STANDARDS LABORATORY



THIS IS PART OF THE LABORATORY DESCRIBED HEREIN

The last few years have seen an increasing number of organizations faced with the problem of setting up an Electrical Standards Laboratory. This is a natural outcome of the general trend to the use of electrical and electronic methods for solving an infinite variety of problems. In addition, our "space age" technology is demanding ever and ever greater levels of accuracies for routine measurements.

The increasing complexity of electrical circuits leads to the products of many manufacturers being pyramided to form one complex pyramid. These factors make it imperative that a volt or an ohm, measured in the plant of manufacturers A, B, C and so on to X, are mutually compatible.

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

S

Symbol of Quality

An increasing number of organizations have been coming to us with the question, "What do we need in the way of equipment and personnel, to provide a satisfactory standards program for our operation?" There is, of course, no single answer to a question such as this. However, to answer as large a percentage of the general inquiries as possible we are devoting this issue of ELECTRICAL MEASUREMENTS to a detailed discussion of setting up a hypothetical small D.C. standards laboratory.

We are making this hypothetical laboratory a small one because, if you have problems enough and money enough to justify a large standards laboratory, you probably also have technically qualified help to establish it. If not, then your first problem can be very simply stated, "Get such a man." The more common situation is a small or medium sized organization, where management finally, and usually reluctantly, decides that money and time must be expended to establish a standards operation. Mr. Smith, Mr. Brown, and Mr. Jones are promptly assigned to the project and after discussing it among themselves find that none of them has any background or experience in electrical standards. To these three gentlemen the following is dedicated.

The first step in establishing a standards laboratory, obviously has to be a survey of the needs and requirements. What ranges of voltage current, resistance, frequencies, and powers are required to be standardized and secondly, to what accuracy do these values need to be standardized? Look at the second question first. If the answer to the required accuracy in the plant turns out to be that no real requirement for measurement accuracies beyond ½ percent or thereabouts are needed in the routine operation, then the problem becomes relatively simple.

If the answer is "requirements of ¼ percent and better are needed in routine factory measurements," then direct reading indicating instruments are readily available in practically all ranges with accuracies of 1/10 percent and ¼ percent. Purchases of a satisfactory range of such reference standard direct indicating instruments literally side-steps what is usually considered standards laboratory operation. In effect it shifts this entirely to the instrument manufacurer's own laboraory. These direct indicating instruments, by having an outside recertification done regularly by either the manufacturer or other recognized standards laboratories, will be ample to assure conformance of factory operations to ½ percent or better.

A perusal of our SENSITIVE RESEARCH Catalogue will show a most satisfactory range of direct reading standards for use where such accuracies are tolerable. Our Models B, L, and LW provide a wide range of voltage, current, and power for both D.C. in the Model B and LW and for A.C. with the L and LW. All of these instruments have basic .1 percent accuracies for use where a reference standard of ¼ percent accuracy is adequate. Our Model C Voltmeters and current instruments for D.C. and the Model D Dynamometers for A.C. measurements of voltage and current are extremely satisfactory instruments with excellent long term stability. For power measurements, our Model DW Wattmeters are in the same accuracy class.

For the small laboratory where even lower accuracies are satisfactory, special attention should be given to the Model S as a D.C. ½ percent instrument with high sensitivity, as well as good accuracy.

For the ultimate in economy, without too great a sacrifice in other characteristics, our UNIVERSITY series of instruments should be considered. In all cases, instruments should be not only accurate but have long scales, well marked, with a mirror for parallax elimination to give adequate resolution as well as accuracy. SENSITIVE RESEARCH is justifiably proud of the hand calibrated scale characteristics and long term stability of our moderately priced instuments.

Management should provide a goodly number of such instruments, with careful storage and handling, a fool proof system for assuring the recertifying of the instruments, and a satisfactory level of personnel to use these instruments to check the working instruments in the plant. Do this and you will have an acceptable standards operation for this level of accuracy.

Ordinarily the term "Standards Laboratory" refers to an electrical certifying organization where accuracies of 1/10 percent or better are expected in the certification of other instruments. To operate in this area, an entirely different basic concept is required. To hold these accuracies some form of long term stability, high accuracy standards are required. Of necessity, these standards MUST originate in an unbroken chain from the National Bureau of Standards.

The magic word "traceability" requires that the links in this chain back to the Bureau be known and documented. It does NOT require that measurements be directly and immediately referred to NBS by means of a single link. The chain can have any number of links or steps between NBS and the measurement being made, providing those steps are satisfactorily documented and reasonable additional tolerances are allowed for each additional step taken. The exact methods of documentation will vary for all of the different types of measurements required. Only very recently have attempts been made to specify the exact steps required in each individual case. It is, however, agreed by all organizations demanding such certifications that the steps be technically sound, that the tolerance must be reasonable and the entire proceedings documented.

Electrical measurements as such, stem from a hierarchy of standards the basis of which is the fundamental D.C. value of the ohm, the volt and the ampere. Elaborate procedures undertaken by various National Standardizing Laboratories have resulted in accurate and maintainable values for the volt and for the ohm, in terms of absolute measurements. By definition, measurements which can be referred directly to length, mass and time, are the basic fundamental units of measurements.

The ampere is basically a transient phenomenon and as such is incapable of being maintained as a satisfactory standard. Hence, it is derived from the two remaining fundamental units; the volt and ohm. The National and legal value of the volt is maintained in the form of a group of saturated cells with an exceptionally long history and maintained in a carefully temperature-controlled oil bath by the National Bureau of Standards. The value of the National Standards is known in terms of absolute values to within some 2 or 3 parts per million.

However, this National Standard is stable and reproducible to small fractions of a micro-volt and comparisons to the National Standard can readily be made to better than tenths of a micro-volt.

...INSTRUMENTS CERTIFY NEW KNOWLEDGE...

Any bank of saturated cells maintained in a carefully thermostated enclosure can be carefully taken to the National Bureau of Standards, compared to the National Standard and returned to your own Standards Laboratory. Including all the possible inaccuracies of comparison and long term stabilities of a standard cell enclosure, such as our SRIC Model 9152, a known value of voltage can then be maintained in your laboratory to within 1 or 2 parts per million. These values can then be relied upon for periods of a year or more between NBS recertifications.

Similarly, a value of resistance in the form of a Thomas or similar type 1 ohm resistances can be compared to the National Standard bank of resistances at NBS and removed to your own laboratory and maintained with an uncertainty in the order of 1 or 2 parts per million. This expected accuracy will be attainable only under relatively ideal conditions and after at least two certifications by NBS to establish a lack of drift in the individual units involved.

It is possible then to establish independent laboratories, values of voltage and resistance with accuracies no worse than a few parts per million. Having a voltage in the order of 1.0185 volts in your laboratory of KNOWN accuracy and a resistor of approximately 1 ohm of KNOWN value will actually allow you to build a complete D.C. standards system, ENTIRELY ON YOUR OWN.

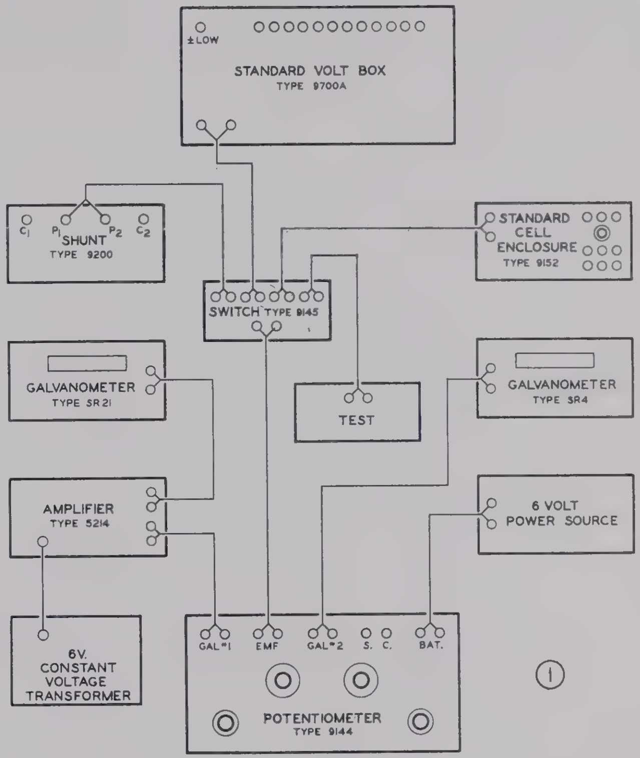
This building of one's own system in their own laboratory based on only these two values is a most IMPORTANT CONCEPT. All other measurements of voltage, resistance or current, can be derived from these values by methods, which are inherently self-checking and provable and do not require reference to any outside facilities whatsoever!

In the case of a resistance, a second resistance can be compared to the known resistance and its error accurately determined by means of many different methods to a degree of accuracy comparable with that which the original resistance was certified. Having checked resistance B against A, you can go further and check C against B, D against C and so on, until you have a group of resistances of similar and equally accurate known values.

If satisfactory comparison methods are used, having known values of A, B, C and D, then this group of resistances can be connected as a ratio device and equally well known ratios can be determined of 1 to 2, 1 to 3, 1 to 4 and so forth. These ratios can then be used to extrapolate, either up or down, for ratios of either resistance or voltage and these ratio methods can be used to extend the voltages DOWN into the micro-volt range and UP into thousands of volts, with each individual step being self-checking and selfproving.

An example of such a device is the potentiometer. A potentiometer consists essentially of a group of resistances, the ratios of which are accurately known and their accuracy of ratio can be selfproved. Many potentiometers, such as the SRIC Model 9144, and others of our Commander Line, make this self proving check convenient by the inclusion of the necessary connections and switching built into the potentiometer itself. However, with sufficient care and patience ANY potentiometer can have its ratio accuracy proved by self-check methods.

Similarly, to extend voltage ranges above the standard cell range, a potentiometer can be used with a volt box. Once again, the volt box is a resistive ratio device and as such is completely self-checkable. The SRIC Model 9700 and 9700A standard volt boxes are excellent examples of highly accurate volt boxes made convenient for self-checking procedures. National Bureau of Standards research paper 1419 describes in great detail the methods of providing these self-check certifications.



The above block diagram shows a very satisfactory standards set-up for maintaining and certifying D.C. instruments. As the standard of voltage, a SRIC Model 9152 standard cell enclosure is used. As a standard of resistance, a type 9200 shunt is shown. This is slightly lower in terms of absolute accuracy than would be an individual Thomas type 1 ohm resistance; but its extremely wide range and convenience justifies its inclusion in this suggested set-up.

These two units are connected through a type 9145 low thermal switch to the input of a Model 9144 potentiometer. The potentiometer is the precision read-out instrument for all of the various measurements to be made with this set-up. It must be provided with an extremely stable six volt power source, which ordinarily consists of a storage battery, which has been charged and connected to the instrument and allowed to stabilize for several days.

The detector in the EMF circuit is shown as SRIC Model 5214 galvanometer amplifier and an SR 21 galvanometer. This provides the ULTIMATE in sensitivity and allows the full fractional part per million resoluton of the potentometer to be used in these measurements. ("You can't read it, if you can't see it.")

This galvanometer amplifier combination will allow single micro-volt differences to be expanded to approximately FULL SCALE on the galvanometer, and thus, the galvanometer resolution is not a limiting factor on any measurements that may be made. For convenience, a standard volt box, the standard cell enclosure, the 9200 shunt and a separate pair of test binding posts for other measurements, are all connected to the input of the potentiometer through the 9145 switch. A second galvanometer, the type SR 4, is shown connected for use with the two internal standard cells provided in the 9144. This is convenient for providing a short term reference without referring back to the 9152, except for the most accurate of measurements.

In this Standard Laboratory, it would be necessary once a year to provide recertification of the 9152 and of the 9200 to maintain satisfactory documentation of the standards operation. The 9144 can be SELF CERTIFIED readily to within an accuracy of fractional parts per million.

In a similar manner, the 9700 A voltbox can be SELF CERTIFIED to within fractional parts per million. This set-up provides the basis of a complete satisfactory system of D.C. measurements in the range from a micro-volt or two, up through 1500 volts and for currents of fractional microamperes, up through 15 amperes.

The basic system required here is the same regardless of the accuracies, which may be required for your own standard operation. If accuracies of a few parts per million are not required, this same system can be operated at much lower levels by using potentiometers with inherently lower accuracies with lower accuracy volt box and shunts and with the saturated standard cell enclosure replaced possibly by a single unsaturated cell.

Under these conditions galvanometers of markedly lower sensitivities can be satisfactorily used. The overall accuracies, or to be more correct, the overall inaccuracy must not add up to greater than the allowed inaccuracies of your own certifications. The basic system is here, you require from some external laboratory a KNOWN voltage standard of a suitable accuracy. You require from an external laboratory a KNOWN resistance standard of suitable accuracy. You require the necessary extrapolation equipment, such as; potentiometer and volt box, which must be of such construction and design as to be stable and reproducable to the accuracies required. You require null detectors with sufficient sensitivity to detect the errors, which may be expected and you require satisfactory D.C. power sources with STABILITIES in the order of the accuracies required.

On page one we show our own D.C. standards laboratory, which contains all the equipment described above. Also shown, is a constant temperature agitated oil bath in which are immerged our standard resistances when used for the most precise measurements. Details of this bath and complete test circuitry are available for purchases of these standards.

LIST OF EQUIPMENT SHOWN IN PHOTOGRAPH

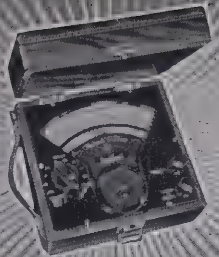
A.	Commander Type 9144 Dauphinee Potentiometer (4 dial—6 figure) 0 to 2.101010 volts in .1 micro-volt steps—stable to better than 1.5 ppm per year	$5,934.00
B.	Commander Type 9700A Volt Ratio Box accuracy ±.001% 25 ranges from .15 volt to 1500 volts—stability ±10 ppm or better per year	$4,456.00
C.	Commander Type 9200 Multirange Standard Resistance (4 terminal resistances) 7 ranges .01 ohm to 10,000 ohms accuracy ±.01%	$ 423.00
D.	Commander Type 9145 Low Thermal Selector Switch (4 DPST sections) (thermal EMF's less than .01 microvolt) (NOT SHOWN)	$ 343.00
E.	Commander Type SR-21 Secondary Galvanometer sensitivity up to 350,000 millimeters per microampere when used with our Type 5214 Amplifier	$ 283.00
F.	Commander Type 5214 Photocell Galvanometer Amplifier (liquid filled to reduce effects of any external mechanical vibration. A 6 volt-15 watt constant voltage transformer is required for the amplifier lamp).	$ 805.00
G.	Commander Type 9152 Constant Temperature Standard Cell Enclosure (contains 4 Type 4305 Saturated Cells — maximum variation ±.01°C. (NOT SHOWN)	$ 979.00
H.	Commander Type 4500/SR-4 Galvanometer Resistance 50 ohms	$ 277.00
I.	6 volt Power Source Low Discharge Type Storage Battery (NOT SHOWN)	

The above equipment described in detail in literature available to you for the asking. We have a 5 year warranty on Potentiometers, Volt Ratio Boxes and Standard Resistances and one year on our portable indicating instruments.

For over 29 years we have published this company bulletin "ELECTRICAL MEASUREMENTS." In it we describe new instruments and measurement techniques. It is sent without cost to interested persons. If you have not been receiving this publication, please advise "SENSITIVE RESEARCH."

Printed in U.S.A.

Prices and specification subject
to change without notice.

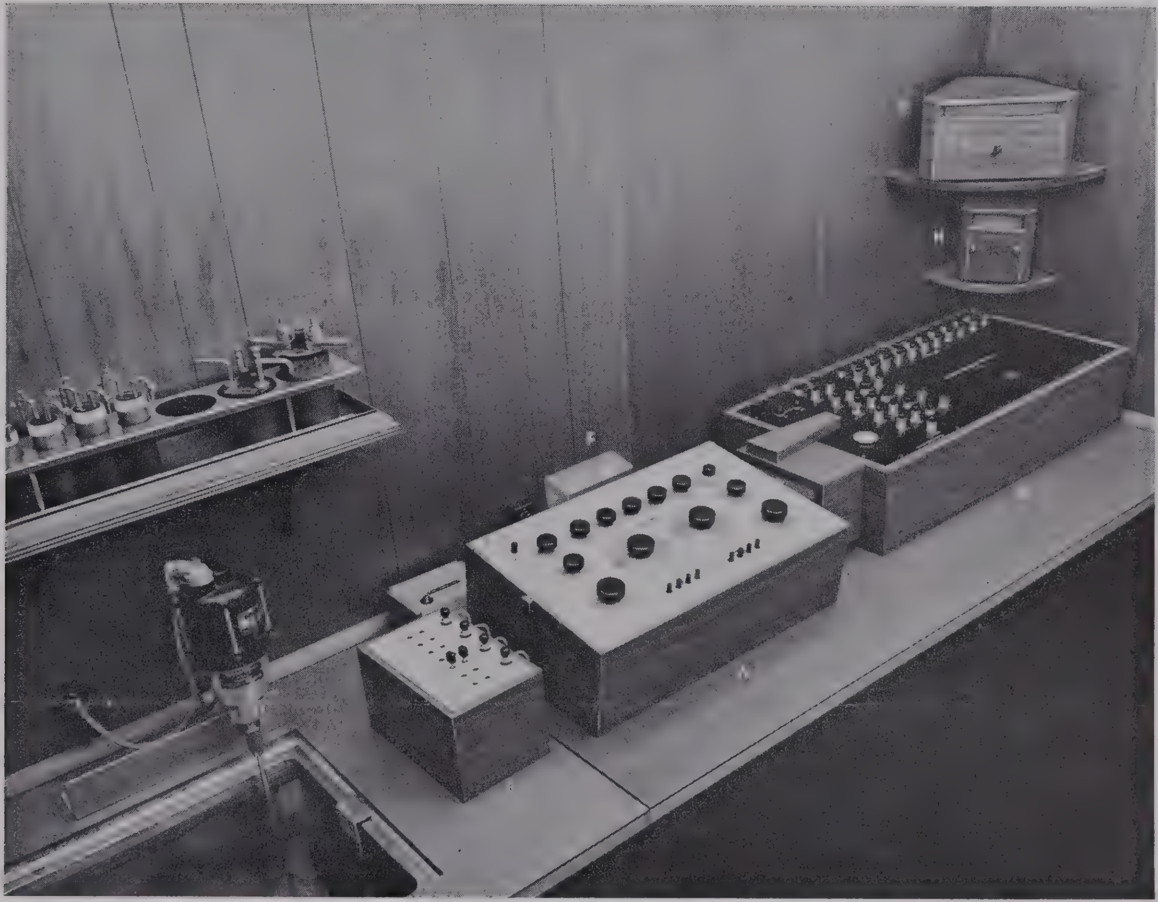


Electrical

MEASUREMENTS

OLUME 29 SEPTEMBER, 1962 VOLUME 9

OUR"
IDEAL SMALL D.C. STANDARDS LABORATORY



THIS IS PART OF THE LABORATORY DESCRIBED HEREIN

The last few years have seen an increasing number of organizations faced with the problem of setting up an Electrical Standards Laboratory. This is a natural outcome of the general trend to the use of electrical and electronic methods for solving an infinite variety of problems. In addition, our "space age" technology is demanding ever and ever greater levels of accuracies for routine measurements.

The increasing complexity of electrical circuits leads to the products of many manufacturers being pyramided to form one complex pyramid. These factors make it imperative that a volt or an ohm, measured in the plant of manufacturers A, B, C and so on to X, are mutually compatible.

SENSITIVE RESEARCH
INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

S

Symbol of Quality

....TO MEASURE IS TO KNOW....

An increasing number of organizations have been coming to us with the question, "What do we need in the way of equipment and personnel, to provide a satisfactory standards program for our operation?" There is, of course, no single answer to a question such as this. However, to answer as large a percentage of the general inquiries as possible we are devoting this issue of ELECTRICAL MEASUREMENTS to a detailed discussion of setting up a hypothetical small D.C. standards laboratory.

We are making this hypothetical laboratory a small one because, if you have problems enough and money enough to justify a large standards laboratory, you probably also have technically qualified help to establish it. If not, then your first problem can be very simply stated, "Get such a man." The more common situation is a small or medium sized organization, where management finally, and usually reluctantly, decides that money and time must be expended to establish a standards operation. Mr. Smith, Mr. Brown, and Mr. Jones are promptly assigned to the project and after discussing it among themselves find that none of them has any background or experience in electrical standards. To these three gentlemen the following is dedicated.

The first step in establishing a standards laboratory, obviously has to be a survey of the needs and requirements. What ranges of voltage current, resistance, frequencies, and powers are required to be standardized and secondly, to what accuracy do these values need to be standardized? Look at the second question first. If the answer to the required accuracy in the plant turns out to be that no real requirement for measurement accuracies beyond ½ percent or thereabouts are needed in the routine operation, then the problem becomes relatively simple.

If the answer is "requirements of ¼ percent and better are needed in routine factory measurements," then direct reading indicating instruments are readily available in practically all ranges with accuracies of 1/10 percent and ¼ percent. Purchases of a satisfactory range of such reference standard direct indicating instruments literally side-steps what is usually considered standards laboratory operation. In effect it shifts this entirely to the instrument manufacurer's own laboraory. These direct indicating instruments, by having an outside recertification done regularly by either the manufacturer or other recognized standards laboratories, will be ample to assure conformance of factory operations to ½ percent or better.

A perusal of our SENSITIVE RESEARCH Catalogue will show a most satisfactory range of direct reading standards for use where such accuracies are tolerable. Our Models B, L, and LW provide a wide range of voltage, current, and power for both D.C. in the Model B and LW and for A.C. with the L and LW. All of these instruments have basic .1 percent accuracies for use where a reference standard of ¼ percent accuracy is adequate. Our Model C Voltmeters and current instruments for D.C. and the Model D Dynamometers for A.C. measurements of voltage and current are extremely satisfactory instruments with excellent long term stability. For power measurements, our Model DW Wattmeters are in the same accuracy class.

For the small laboratory where even lower accuracies are satisfactory, special attention should be given to the Model S as a D.C. ½ percent instrument with high sensitivity, as well as good accuracy.

For the ultimate in economy, without too great a sacrifice in other characteristics, our UNIVERSITY series of instrument should be considered. In all cases, instruments should be not only accurate but have long scales, well marked, with a mirror for parallax elimination to give adequate resolution as well as accuracy. SENSITIVE RESEARCH is justifiably proud of the hand calibrated scale characteristics and long term stability of our moderately priced instuments.

Management should provide a goodly number of such instruments, with careful storage and handling, a fool proof system for assuring the recertifying of the instruments, and a satisfactory level of personnel to use these instruments to check the working instruments in the plant. Do this and you will have an acceptable standards operation for this level of accuracy.

Ordinarily the term "Standards Laboratory" refers to an electrical certifying organization where accuracies of 1/10 percent or better are expected in the certification of other instruments. To operate in this area, an entirely different basic concept is required. To hold these accuracies some form of long term stability, high accuracy standards are required. Of necessity, these standards MUST originate in an unbroken chain from the National Bureau of Standards.

The magic word "traceability" requires that the links in this chain back to the Bureau be known and documented. It does NOT require that measurements be directly and immediately referred to NBS by means of a single link. The chain can have any number of links or steps between NBS and the measurement being made, providing those steps are satisfactorily documented and reasonable additional tolerances are allowed for each additional step taken. The exact methods of documentation will vary for all of the different types of measurements required. Only very recently have attempts been made to specify the exact steps required in each individual case. It is, however, agreed by all organizations demanding such certifications that the steps be technically sound, that the tolerance must be reasonable and the entire proceedings documented.

Electrical measurements as such, stem from a hierarchy of standards the basis of which is the fundamental D.C. value of the ohm, the volt and the ampere. Elaborate procedures undertaken by various National Standardizing Laboratories have resulted in accurate and maintainable values for the volt and for the ohm, in terms of absolute measurements. By definition, measurements which can be referred directly to length, mass and time, are the basic fundamental units of measurements.

The ampere is basically a transient phenomenon and as such is incapable of being maintained as a satisfactory standard. Hence, it is derived from the two remaining fundamental units; the volt and ohm. The National and legal value of the volt is maintained in the form of a group of saturated cells with an exceptionally long history and maintained in a carefully temperature-controlled oil bath by the National Bureau of Standards. The value of the National Standards is known in terms of absolute values to within some 2 or 3 parts per million.

However, this National Standard is stable and reproducible to small fractions of a micro-volt and comparisons to the National Standard can readily be made to better than tenths of a micro-volt.

...INSTRUMENTS CERTIFY NEW KNOWLEDGE...

Any bank of saturated cells maintained in a carefully thermostated enclosure can be carefully taken to the National Bureau of Standards, compared to the National Standard and returned to your own Standards Laboratory. Including all the possible inaccuracies of comparison and long term stabilities of a standard cell enclosure, such as our SRIC Model 9152, a known value of voltage can then be maintained in your laboratory to within 1 or 2 parts per million. These values can then be relied upon for periods of a year or more between NBS recertifications.

Similarly, a value of resistance in the form of a Thomas or similar type 1 ohm resistances can be compared to the National Standard bank of resistances at NBS and removed to your own laboratory and maintained with an uncertainty in the order of 1 or 2 parts per million. This expected accuracy will be attainable only under relatively ideal conditions and after at least two certifications by NBS to establish a lack of drift in the individual units involved.

It is possible then to establish independent laboratories, values of voltage and resistance with accuracies no worse than a few parts per million. Having a voltage in the order of 1.0185 volts in your laboratory of KNOWN accuracy and a resistor of approximately 1 ohm of KNOWN value will actually allow you to build a complete D.C. standards system, ENTIRELY ON YOUR OWN.

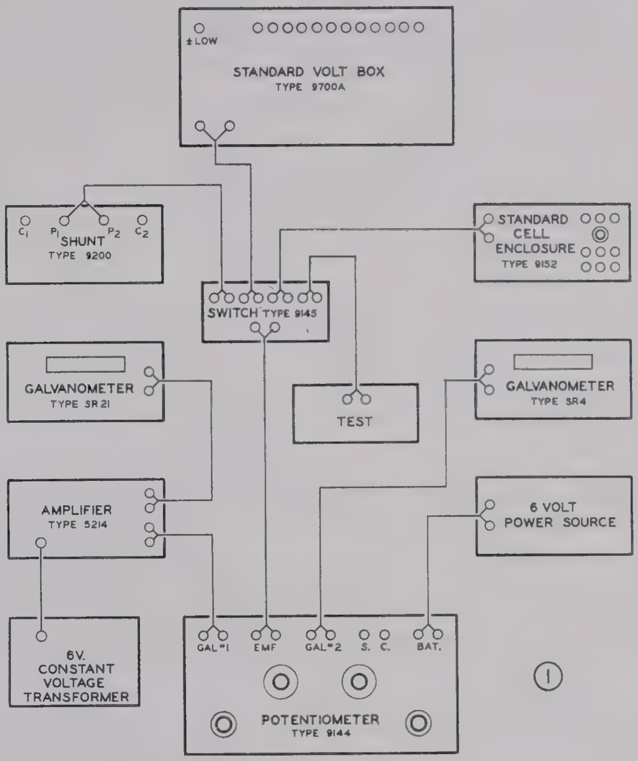
This building of one's own system in their own laboratory based on only these two values is a most IMPORTANT CONCEPT. All other measurements of voltage, resistance or current, can be derived from these values by methods, which are inherently self-checking and provable and do not require reference to any outside facilities whatsoever!

In the case of a resistance, a second resistance can be compared to the known resistance and its error accurately determined by means of many different methods to a degree of accuracy comparable with that which the original resistance was certified. Having checked resistance B against A, you can go further and check C against B, D against C and so on, until you have a group of resistances of similar and equally accurate known values.

If satisfactory comparison methods are used, having known values of A, B, C and D, then this group of resistances can be connected as a ratio device and equally well known ratios can be determined of 1 to 2, 1 to 3, 1 to 4 and so forth. These ratios can then be used to extrapolate, either up or down, for ratios of either resistance or voltage and these ratio methods can be used to extend the voltages DOWN into the micro-volt range and UP into thousands of volts, with each individual step being self-checking and selfproving.

An example of such a device is the potentiometer. A potentiometer consists essentially of a group of resistances, the ratios of which are accurately known and their accuracy of ratio can be selfproved. Many potentiometers, such as the SRIC Model 9144, and others of our Commander Line, make this self proving check convenient by the inclusion of the necessary connections and switching built into the potentiometer itself. However, with sufficient care and patience ANY potentiometer can have its ratio accuracy proved by self-check methods.

Similarly, to extend voltage ranges above the standard cell range, a potentiometer can be used with a volt box. Once again, the volt box is a resistive ratio device and as such is completely self-checkable. The SRIC Model 9700 and 9700A standard volt boxes are excellent examples of highly accurate volt boxes made convenient for self-checking procedures. National Bureau of Standards research paper 1419 describes in great detail the methods of providing these self-check certifications.



The above block diagram shows a very satisfactory standards set-up for maintaining and certifying D.C. instruments. As the standard of voltage, a SRIC Model 9152 standard cell enclosure is used. As a standard of resistance, a type 9200 shunt is shown. This is slightly lower in terms of absolute accuracy than would be an individual Thomas type 1 ohm resistance; but its extremely wide range and convenience justifies its inclusion in this suggested set-up.

These two units are connected through a type 9145 low thermal switch to the input of a Model 9144 potentiometer. The potentiometer is the precision read-out instrument for all of the various measurements to be made with this set-up. It must be provided with an extremely stable six volt power source, which ordinarily consists of a storage battery, which has been charged and connected to the instrument and allowed to stabilize for several days.

The detector in the EMF circuit is shown as SRIC Model 5214 galvanometer amplifier and an SR 21 galvanometer. This provides the ULTIMATE in sensitivity and allows the full fractional part per million resoluton of the potentometer to be used in these measurements. ("You can't read it, if you can't see it.")

...MEASUREMENT IS THE BASIS OF PROGRESS...

This galvanometer amplifier combination will allow single micro-volt differences to be expanded to approximately FULL SCALE on the galvanometer, and thus, the galvanometer resolution is not a limiting factor on any measurements that may be made. For convenience, a standard volt box, the standard cell enclosure, the 9200 shunt and a separate pair of test binding posts for other measurements, are all connected to the input of the potentiometer through the 9145 switch. A second galvanometer, the type SR 4, is shown connected for use with the two internal standard cells provided in the 9144. This is convenient for providing a short term reference without referring back to the 9152, except for the most accurate of measurements.

In this Standard Laboratory, it would be necessary once a year to provide recertification of the 9152 and of the 9200 to maintain satisfactory documentation of the standards operation. The 9144 can be SELF CERTIFIED readily to within an accuracy of fractional parts per million.

In a similar manner, the 9700 A voltbox can be SELF CERTIFIED to within fractional parts per million. This set-up provides the basis of a complete satisfactory system of D.C. measurements in the range from a micro-volt or two, up through 1500 volts and for currents of fractional microamperes, up through 15 amperes.

The basic system required here is the same regardless of the accuracies, which may be required for your own standard operation. If accuracies of a few parts per million are not required, this same system can be operated at much lower levels by using potentiometers with inherently lower accuracies with lower accuracy volt box and shunts and with the saturated standard cell enclosure replaced possibly by a single unsaturated cell.

Under these conditions galvanometers of markedly lower sensitivities can be satisfactorily used. The overall accuracies, or to be more correct, the overall inaccuracy must not add up to greater than the allowed inaccuracies of your own certifications. The basic system is here, you require from some external laboratory a KNOWN voltage standard of a suitable accuracy. You require from an external laboratory a KNOWN resistance standard of suitable accuracy. You require the necessary extrapolation equipment, such as; potentiometer and volt box, which must be of such construction and design as to be stable and reproducible to the accuracies required. You require null detectors with sufficient sensitivity to detect the errors, which may be expected and you require satisfactory D.C. power sources with STABILITIES in the order of the accuracies required.

On page one we show our own D.C. standards laboratory, which contains all the equipment described above. Also shown, is a constant temperature agitated oil bath in which are immerged our standard resistances when used for the most precise measurements. Details of this bath and complete test circuitry are available for purchases of these standards.

LIST OF EQUIPMENT SHOWN IN PHOTOGRAPH

A.	Commander Type 9144 Dauphinee Potentiometer (4 dial—6 figure) 0 to 2.101010 volts in .1 micro-volt steps—stable to better than 1.5 ppm per year	$5,934.00
B.	Commander Type 9700A Volt Ratio Box accuracy ±.001% 25 ranges from .15 volt to 1500 volts—stability ±10 ppm or better per year	$4,456.00
C.	Commander Type 9200 Multirange Standard Resistance (4 terminal resistances) 7 ranges .01 ohm to 10,000 ohms accuracy ±.01%	$ 423.00
D.	Commander Type 9145 Low Thermal Selector Switch (4 DPST sections) (thermal EMF's less than .01 microvolt) (NOT SHOWN)	$ 343.00
E.	Commander Type SR-21 Secondary Galvanometer sensitivity up to 350,000 millimeters per microampere when used with our Type 5214 Amplifier	$ 283.00
F.	Commander Type 5214 Photocell Galvanometer Amplifier (liquid filled to reduce effects of any external mechanical vibration. A 6 volt-15 watt constant voltage transformer is required for the amplifier lamp).	$ 805.00
G.	Commander Type 9152 Constant Temperature Standard Cell Enclosure (contains 4 Type 4305 Saturated Cells — maximum variation ±.01°C. (NOT SHOWN)	$ 979.00
H.	Commander Type 4500/SR-4 Galvanometer Resistance 50 ohms	$ 277.00
I.	6 volt Power Source Low Discharge Type Storage Battery (NOT SHOWN)	

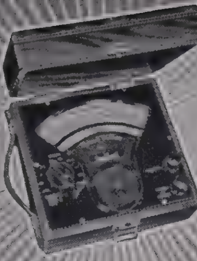
The above equipment described in detail in literature available to you for the asking. We have a 5 year warranty on Potentiometers, Volt Ratio Boxes and Standard Resistances and one year on our portable indicating instruments.

◆

For over 29 years we have published this company bulletin "ELECTRICAL MEASUREMENTS." In it we describe new instruments and measurement techniques. It is sent without cost to interested persons. If you have not been receiving this publication, please advise "SENSITIVE RESEARCH."

Printed in U.S.A.

Prices and specification subject
to change without notice.



Electrical MEASUREMENTS

VOLUME 29 JUNE, 1962 NUMBER 6

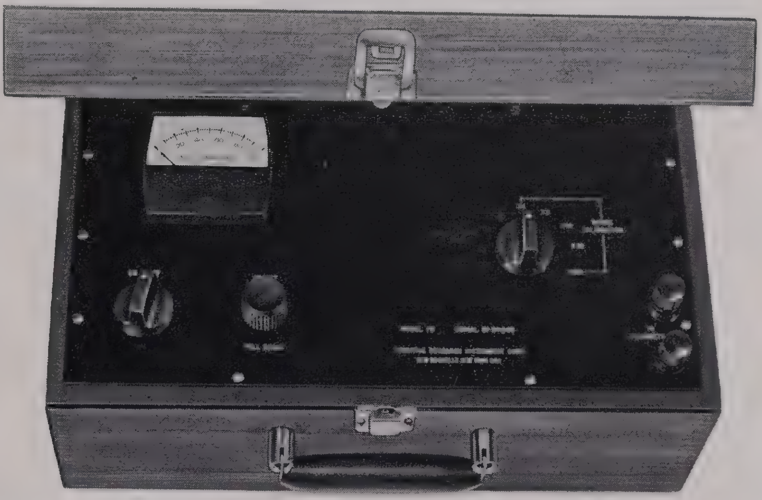
JUL 17 1962

SELF CHECKING!

10 INCH VERNIER D. C. POLYRANGER
and a
FLUXMETER CALIBRATOR

NEW!

MODEL FC



FLUXMETER CALIBRATOR
ACCURACY
.2 OF 1%

Our SENSITIVE RESEARCH FLUXMETER which we have built the past 35 years has an extremely versatile usage in magnetic measurements. Besides its basic use for the measurement of flux linkages, by means of a search coil, it is also used in many other applications where its ability to integrate voltage or current with time is of value.

Calibrations on these instruments are made in terms of milliampere seconds, of coulombs discharged through specific resistances, and many other methods. In the same manner that it is used in such a wide variety of applications it has also been calibrated in a wide variety of ways.

Calibration equipment for use with this instrument have included many different forms of mutual inductors in which a primary current was started, stopped or reversed to provide a known or calculable number of flux line changes in the secondary. Calibrations have also been performed using accurately monitored currents for known lengths of time. Calibrations of a fluxmeter have also been made by charging an accurately known capacitor to a specified voltage and using the discharge of this capacitor for calibration purposes. Standard magnets and search coils have also been used for 1 percent measurement.

The new Model FC Fluxmeter Calibrator being introduced by SRIC uses the mutual inductance calibration method. For high accuracy and long term stability mutual inductors with air cores have traditionally been used. However, when we start considering the design of a satisfactory air core mutual inductor for use in fluxmeter calibrations of an instrument with as wide ranges as the SENSITIVE RESEARCH Model FM, difficulties are encountered.

SENSITIVE RESEARCH INSTRUMENT CORPORATION

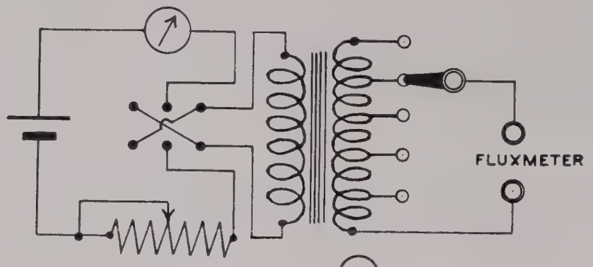
NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

S

Symbol of Quality

The secondary resistance must be kept to not more than 15 ohms, yet the total number of turns required is extremely high in order to produce a satisfactory value of mutual inductance to allow calibration of its X100 range with reasonable primary currents. This leads to impossibly large and expensive inductors. Thanks to wide spread development in the magnetic amplifier field, high permeability tape wound magnetic cores are available in "Square Loop" type materials. Full advantage of these specialized materials have been taken in the design of the Model FC.



①

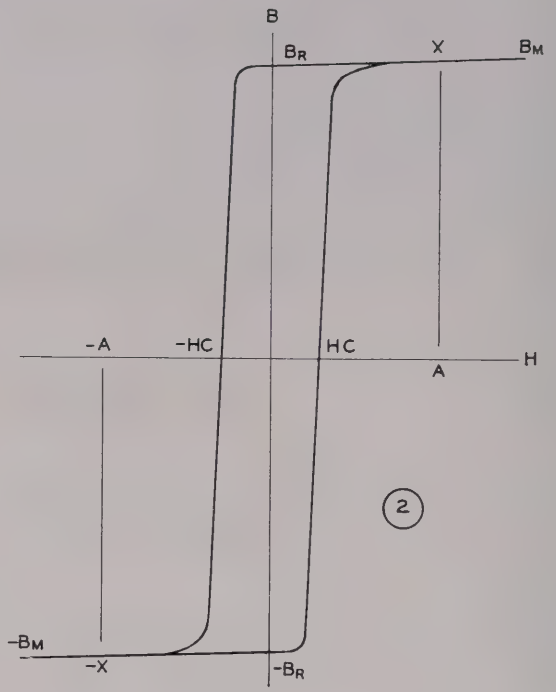
The basic circuit used is shown in figure 1. Current from an internal battery source is fed through an adjusting rheostat and a monitoring current meter, through a reversing switch to the primary of a transformer using a square loop type core material. A secondary with taps to adjust to an appropriate number of turns is used to sense the flux reversals in the core and these flux reversals constitute the calibration energy for the fluxmeter.

In figure 2 is shown a typical hyteresis loop for the type of core material used in the calibrator. It will be seen that once excitations slightly beyond the HC value are used that the values of Bmax is substantially stable regardless of variation in the value of H. For purposes of our calibrator a value of H is chosen at A. This allows the core to traverse the hysteresis loop from point X to —X or vice versa. For each complete reversal of the primary current it will be noticed that at the points the BH loop is, in effect, a single line and its slope is nearly, but not exactly, horizontal. This effect is taken advantage of in this calibrator. The fact that it is nearly horizontal means that if the primary current is measured to a relatively rough accuracy the total flux reversals will be very accurately determined.

Variations of ± 5% in the value of H (exciting current) will change total flux densitites by less than .05%. This lack of sensitivity to exciting current allows the use of a relatively small inexpensive indicating instrument and still maintain a high degree of calibration accuracy. However, the fact that the changes are present, even though small, allows for a very satisfactory adjustment of the final calibration point by moving the point X large amounts in either direction.

This can be done by either a change in meter sensitivity or a change in primary turns or a combination of both.

Due to the extremely high permeability of the core material, as soon as any one of the secondary tap points is adjusted satisfactory for its range all the others will automatically fall in line directly proportional to the number of turns involved. This is true to the extent that core permeability is higher than air, a factor of 40,000 to 1. In addition the coil design includes an extremely low primary — secondary capacitance to eliminate error from the conductance of this capacity.



②

The standard Model FC has appropriately proportioned tap points of the secondary to provide calibrations for each of the cardinal points on the standard Model FM Fluxmeter. In addition, it also provides a full scale point for each of the multiplier ranges. This allows a complete recertification of our fluxmeters on all ranges to a basic accuracy of .2 of 1% of any of the calibrating points. All of these various output ranges are made up to an exact 15 ohms for use in calibrating our FS and FM models. In addition, temperature compensation is applied to all ranges of the calibrator. The instrument is certified at a temperature of 25°C and will have a temperature coefficient not worse than .04% per degree C. This correction will be constant and linear, and will be marked on the calibration certificate furnished with the instrument. If operation at extremes of temperatures should be required the necessary correction factor can be readily applied.

Operation of the instrument is extremely simple. The fluxmeter is connected to the binding posts of the calibrator, the range switch set to the desired check point, the current is then adjusted by means of the rheostat to the red calibration line of the panel instrument, and one or two current reversals made with the panel reversing switch. The fluxmeter is then carefully zeroed and the reversing switch thrown. This will provide an output pulse which will bring the fluxmeter point to the exact value set. Complete instructions with calibrator.

MODEL FC
FLUXMETER CALIBRATOR

*PRICE $342.00

ACCURACY — .2 of 1 percent

RANGES — Full scale points for the X1, X3, X10, X30X100 ranges of the Model FM (SRIC Fluxmeter) AND the 10 - 20 - 30 - 40 - 50 division points on its X1 range only.

The above values are for standard 10000 lines per division instruments.

CASE — 13¾" x 7½" x 6½".

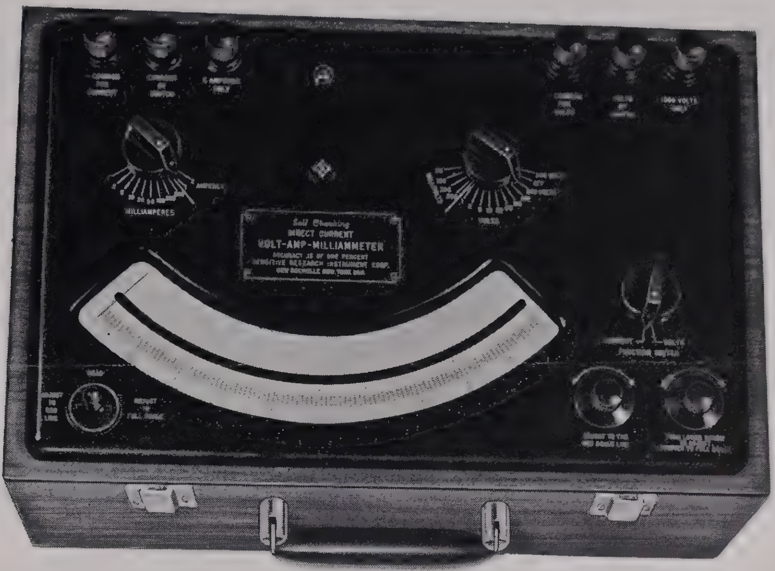
WEIGHTS — 12 lbs. Shipping 26 lbs.

POWER SUPPLY — 2 #RM-42R Mallory batteries or equal. (Replaced from back of case.)

* This calibrator can be supplied for rack mounting on a standard, 19" x 7" x ⅛" aluminum panel. (GRAY is standard.) Additional cost $50.00.

A "SELF CHECKING" 10 INCH VERNIER D.C. POLYRANGER

MODEL **SCP**



OVERALL
ACCURACY .15 OF 1%

Engineering design is always a continuing series of compromises. A matching of many contradictory design requirements to arrive at an optimum overall solution is the usual designer's headache. It seems that no sooner are these compromises made to a point where they seem sane and reasonable then some new technique crosses the horizon and requires a complete re-evaluation.

Many years ago, engineers arrived at an optimum portable panel instrument with something in the order of a 6" scale. A number of laboratory standard instruments were made with 12" scales; however, these were strictly limited in ranges and power consumed because of a relatively long, heavy pointer with correspondingly heavier moving parts.

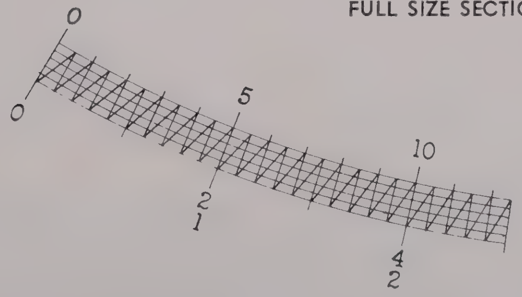
SENSITIVE RESEARCH pioneered the use of "Self-Checking" circuits for improvement of the basic long term stability and accuracy of instruments. Because of these factors, we have worked ourselves into an engineering corner where the design compromises need to be re-evaluated.

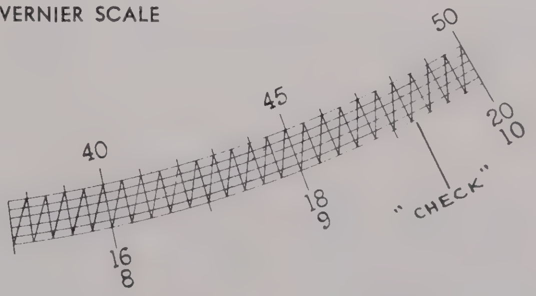
Due to our improved ability to self-check instruments the long term stability and the basic accuracy of the instruments is so excellent that the actual readability of the scale becomes a LIMITING FACTOR. Rather than go to the 12" scale instrument with its realtively heavy massive moving system, it seems justified at this time to introduce an intermediate design.

Our new SRIC Model SCP 10 inch volt-amp-milliammeter is the first instrument embodying this compromise movement. The scale readability has been increased to a point where it is comparable with the actual accuracy of the instrument and yet the mechanical characteristics of the instrument are such that we can still operate with a very reasonable degree of sensitivity.

It would seem that this basic new instrument design might very well be the forerunner of many instruments which could take advantage of this somewhat new and different compromise in DC movement characteristics.

FULL SIZE SECTIONS OF THE 10 INCH VERNIER SCALE





...MEASUREMENT IS THE BASIS OF PROGRESS...

Our original DC POLYRANGER was designed in 1927 as the first practical double pivoted Multirange Milliammeter-Voltmeter with a resistance as high as 10,000 ohms per volt. Since that time, the original design has been enlarged to include the world's finest selection of true poly-range instruments, both AC and DC.

Our POLYRANGER designs appeal to those discriminating people who want personal precision instruments, with which they can be assured of being able to measure accurately the various values of current or voltage essential to modern research.

This new Model SCP Direct Current POLYRANGER, with its 10 inch vernier scale has internal circuitry and a self contained battery to check its full scale points to within .075 of 1%. When adjusted and self-checked all the points on its 10 inch scale will be within .15 of 1% and its top point will be within .075 of 1%. This new POLYRANGER has 26 ranges. There are 14 ranges in volts and millivolts. The lowest range is 50 millivolts full scale. The highest is 1000 volts. (The 50 and 100 millivolt ranges are particularly well adapted for the use of external shunts.)

There are 12 current ranges from one milliampere full scale to 5 amperes full scale.

The Voltage and Current sections are COMPLETELY separated from each other. This means that both current and voltage can be applied to the Polyranger at the same time. A function switch on its panel selects the circuits to be used. Dummy loads are automatically placed in both the current and volt circuits so that the external circuit not being measured is undisturbed.

The ability to "self-check" its own accuracy is of great value to any user of the instrument. We use zero temperature coefficient zener diodes to create the equivalent of a standard cell reference circuit which is internal battery operated. The reference voltage thus obtained is accurate to .01 percent.

There are lines on the scale to which the pointer is adjusted by internal rheostats by the user. This procedure only takes a few monments. When accomplished the engineer is assured that he has a precise instrument in his possession for immediate use.

We also have two small red colored binding posts on the instrument panel. When the pointer is correctly adjusted to full scale, there will appear 1 volt at these posts with an accuracy of .075 of 1%. The user can, if desired, use an outside potentiometer to verify the instrument's accuracy if there is ever a question of its internal check circuit and its .075 of 1% of full scale accuracy.

This 10" long vernier scale, very accurate multirange instrument will be a valuable asset to a progressive busy engineer or laboratory with its ability to self-check its own scale without its going back to the standards division.

SELF CHECKING
DIRECT CURRENT POLYRANGER
MODEL SCP

26 RANGES (FULL SCALE VALUES) — PRICE $725.00

50/100/200/500 Millivolts
1/2/5/10/20/50/100/200/500/1000 Volts
(1000 ohms per volt)
1/2/5/10/20/50/100/200/500 Milliamperes
1/2/5 Amperes

ACCURACY — (.075 of 1%) When self-checked at full scale
ACCURACY — (.15 of 1%) Overall accuracy
SCALE LENGTH — 10 inches
SCALE DIVISIONS — 100 (Vernier) type (see picture page 3)
RESOLUTION BY VERNIER TO .2 DIVISION
Can be readily interpolated to .1 DIVISION
SELF CHECKING
INTERNALLY SWITCHED — ACCOMPLISHED IN A FEW MOMENTS — INTERNAL BATTERY readily replaced from bottom of case
CASE — FORMICA (WALNUT) WITH REMOVABLE COVER
15⅞" x 10⅜" x 8"
INSTRUCTIONS — COMES WITH EACH POLYRANGER
APPROXIMATE WEIGHTS — 21 lbs. — Shipping 37 lbs.

◆

ANNOUNCEMENT

We are always looking for new ideas that will advance the state of the intrument makers art.

If you have any undeveloped or completed ideas we would be very glad to correspond with you. We can, if required, undertake the industrial development of new measurement or allied products.

However, be warned that for your own protection you should not send in new, ingenious devices until you have obtained a patent or at least filed a patent application to protect yourself.

As this company has a very active R & D department we coincidentally could be working on an idea that might be similar to yours.

We wish to remain friends with one and all — THEREFORE — please drop us a line before you send specific details.

For over 30 years we have published this company bulletin "ELECTRICAL MEASUREMENTS." In it we describe new instruments and measurements techniques. It is sent without cost to interested persons.

If you have not been receiving this publication, please advise

SENSITIVE RESEARCH INSTRUMENT CORP.
310-316 Main Street
New Rochelle, New York, U.S.A.

SENSITIVE RESEARCH instruments are unconditionally guaranteed as to workmanship and materials for a period of one year. We guarantee our instruments to maintain their described accuracies, provided they are not abused and that the instrument seal is not broken.

Printed in U.S.A.

Prices and specifications subject to change without notice.

Electrical
MEASUREMENTS

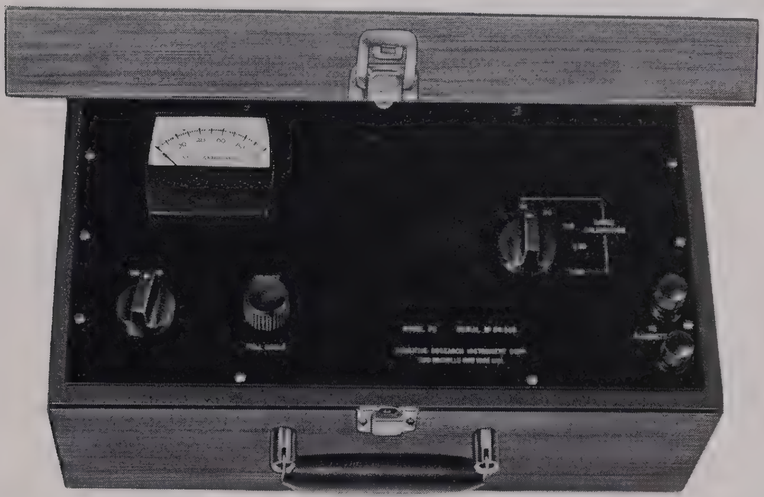
JUL 17 1962 AM

VOLUME 29 JUNE, 1962 NUMBER 6

SELF CHECKING!
10 INCH VERNIER D. C. POLYRANGER
and a
FLUXMETER CALIBRATOR

NEW!

MODEL FC



FLUXMETER CALIBRATOR
ACCURACY
.2 OF 1%

Our SENSITIVE RESEARCH FLUXMETER which we have built the past 35 years has an extremely versatile usage in magnetic measurements. Besides its basic use for the measurement of flux linkages, by means of a search coil, it is also used in many other applications where its ability to integrate voltage or current with time is of value.

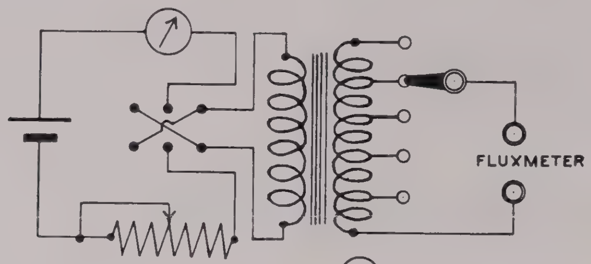
Calibrations on these instruments are made in terms of milliampere seconds, of coulombs discharged through specific resistances, and many other methods. In the same manner that it is used in such a wide variety of applications it has also been calibrated in a wide variety of ways.

Calibration equipment for use with this instrument have included many different forms of mutual inductors in which a primary current was started, stopped or reversed to provide a known or calculable number of flux line changes in the secondary. Calibrations have also been performed using accurately monitored currents for known lengths of time. Calibrations of a fluxmeter have also been made by charging an accurately known capacitor to a specified voltage and using the discharge of this capacitor for calibration purposes. Standard magnets and search coils have also been used for 1 percent measurement.

The new Model FC Fluxmeter Calibrator being introduced by SRIC uses the mutual inductance calibration method. For high accuracy and long term stability mutual inductors with air cores have traditionally been used. However, when we start considering the design of a satisfactory air core mutual inductor for use in fluxmeter calibrations of an instrument with as wide ranges as the SENSITIVE RESEARCH Model FM, difficulties are encountered.

SENSITIVE RESEARCH INSTRUMENT CORPORATION
NEW ROCHELLE, N. Y.
ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927
Symbol of Quality

The secondary resistance must be kept to not more than 15 ohms, yet the total number of turns required is extremely high in order to produce a satisfactory value of mutual inductance to allow calibration of its X100 range with reasonable primary currents. This leads to impossibly large and expensive inductors. Thanks to wide spread development in the magnetic amplifier field, high permeability tape wound magnetic cores are available in "Square Loop" type materials. Full advantage of these specialized materials have been taken in the design of the Model FC.



①

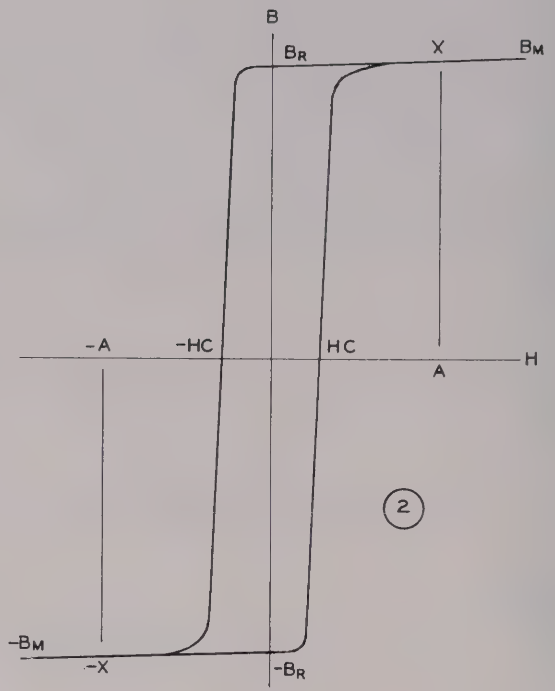
The basic circuit used is shown in figure 1. Current from an internal battery source is fed through an adjusting rheostat and a monitoring current meter, through a reversing switch to the primary of a transformer using a square loop type core material. A secondary with taps to adjust to an appropriate number of turns is used to sense the flux reversals in the core and these flux reversals constitute the calibration energy for the fluxmeter.

In figure 2 is shown a typical hyteresis loop for the type of core material used in the calibrator. It will be seen that once excitations slightly beyond the HC value are used that the values of Bmax is substantially stable regardless of variation in the value of H. For purposes of our calibrator a value of H is chosen at A. This allows the core to traverse the hysteresis loop from point X to —X or vice versa. For each complete reversal of the primary current it will be noticed that at the points the BH loop is, in effect, a single line and its slope is nearly, but not exactly, horizontal. This effect is taken advantage of in this calibrator. The fact that it is nearly horizontal means that if the primary current is measured to a relatively rough accuracy the total flux reversals will be very accurately determined.

Variations of ± 5% in the value of H (exciting current) will change total flux densitites by less than .05%. This lack of sensitivity to exciting current allows the use of a relatively small inexpensive indicating instrument and still maintain a high degree of calibration accuracy. However, the fact that the changes are present, even though small, allows for a very satisfactory adjustment of the final calibration point by moving the point X large amounts in either direction.

This can be done by either a change in meter sensitivity or a change in primary turns or a combination of both.

Due to the extremely high permeability of the core material, as soon as any one of the secondary tap points is adjusted satisfactory for its range all the others will automatically fall in line directly proportional to the number of turns involved. This is true to the extent that core permeability is higher than air, a factor of 40,000 to 1. In addition the coil design includes an extremely low primary — secondary capacitance to eliminate error from the conductance of this capacity.



②

The standard Model FC has appropriately proportioned tap points of the secondary to provide calibrations for each of the cardinal points on the standard Model FM Fluxmeter. In addition, it also provides a full scale point for each of the multiplier ranges. This allows a complete recertification of our fluxmeters on all ranges to a basic accuracy of .2 of 1% of any of the calibrating points. All of these various output ranges are made up to an exact 15 ohms for use in calibrating our FS and FM models. In addition, temperature compensation is applied to all ranges of the calibrator. The instrument is certified at a temperature of 25°C and will have a temperature coefficient not worse than .04% per degree C. This correction will be constant and linear, and will be marked on the calibration certificate furnished with the instrument. If operation at extremes of temperatures should be required the necessary correction factor can be readily applied.

Operation of the instrument is extremely simple. The fluxmeter is connected to the binding posts of the calibrator, the range switch set to the desired check point, the current is then adjusted by means of the rheostat to the red calibration line of the panel instrument, and one or two current reversals made with the panel reversing switch. The fluxmeter is then carefully zeroed and the reversing switch thrown. This will provide an output pulse which will bring the fluxmeter point to the exact value set. Complete instructions with calibrator.

MODEL FC

FLUXMETER CALIBRATOR

*PRICE $342.00

ACCURACY — .2 of 1 percent

RANGES — Full scale points for the X1, X3, X10, X30X100 ranges of the Model FM (SRIC Fluxmeter) AND the 10 - 20 - 30 - 40 - 50 division points on its X1 range only.

The above values are for standard 10000 lines per division instruments.

CASE — 13¾" x 7½" x 6½".

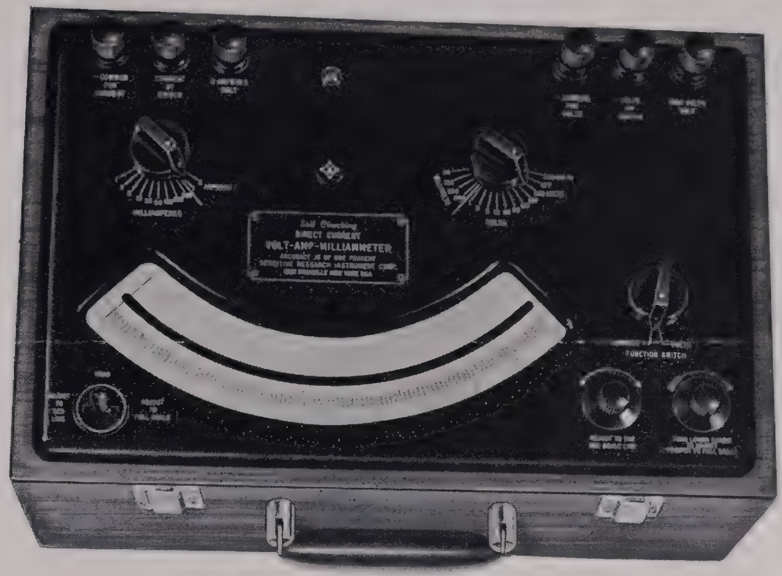
WEIGHTS — 12 lbs. Shipping 26 lbs.

POWER SUPPLY — 2 #RM—42R Mallory batteries or equal. (Replaced from back of case.)

* This calibrator can be supplied for rack mounting on a standard, 19" x 7" x ⅛" aluminum panel. (GRAY is standard.) Additional cost $50.00.

A "SELF CHECKING" 10 INCH VERNIER D.C. POLYRANGER

MODEL **SCP**



OVERALL
ACCURACY .15 OF 1%

Engineering design is always a continuing series of compromises. A matching of many contradictory design requirements to arrive at an optimum overall solution is the usual designer's headache. It seems that no sooner are these compromises made to a point where they seem sane and reasonable then some new technique crosses the horizon and requires a complete re-evaluation.

Many years ago, engineers arrived at an optimum portable panel instrument with something in the order of a 6" scale. A number of laboratory standard instruments were made with 12" scales; however, these were strictly limited in ranges and power consumed because of a relatively long, heavy pointer with correspondingly heavier moving parts.

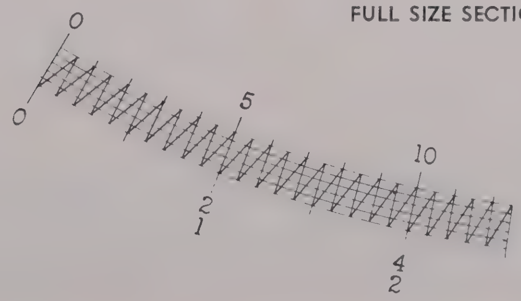
SENSITIVE RESEARCH pioneered the use of "Self-Checking" circuits for improvement of the basic long term stability and accuracy of instruments. Because of these factors, we have worked ourselves into an engineering corner where the design compromises need to be re-evaluated.

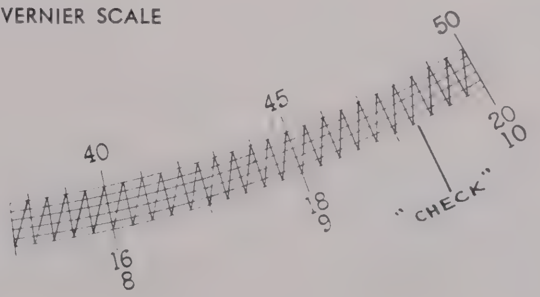
Due to our improved ability to self-check instruments the long term stability and the basic accuracy of the instruments is so excellent that the actual readability of the scale becomes a LIMITING FACTOR. Rather than go to the 12" scale instrument with its realtively heavy massive moving system, it seems justified at this time to introduce an intermediate design.

Our new SRIC Model SCP 10 inch volt-amp-milliammeter is the first instrument embodying this compromise movement. The scale readability has been increased to a point where it is comparable with the actual accuracy of the instrument and yet the mechanical characteristics of the instrument are such that we can still operate with a very reasonable degree of sensitivity.

It would seem that this basic new instrument design might very well be the forerunner of many instruments which could take advantage of this somewhat new and different compromise in DC movement characteristics.

FULL SIZE SECTIONS OF THE 10 INCH VERNIER SCALE





...MEASUREMENT IS THE BASIS OF PROGRESS...

Our original DC POLYRANGER was designed in 1927 as the first practical double pivoted Multirange Milliammeter-Voltmeter with a resistance as high as 10,000 ohms per volt. Since that time, the original design has been enlarged to include the world's finest selection of true poly-range instruments, both AC and DC.

Our POLYRANGER designs appeal to those discriminating people who want personal precision instruments, with which they can be assured of being able to measure accurately the various values of current or voltage essential to modern research.

This new Model SCP Direct Current POLYRANGER, with its 10 inch vernier scale has internal circuitry and a self contained battery to check its full scale points to within .075 of 1%. When adjusted and self-checked all the points on its 10 inch scale will be within .15 of 1% and its top point will be within .075 of 1%. This new POLYRANGER has 26 ranges. There are 14 ranges in volts and millivolts. The lowest range is 50 millivolts full scale. The highest is 1000 volts. (The 50 and 100 millivolt ranges are particularly well adapted for the use of external shunts.)

There are 12 current ranges from one milliampere full scale to 5 amperes full scale.

The Voltage and Current sections are COMPLETELY separated from each other. This means that both current and voltage can be applied to the Polyranger at the same time. A function switch on its panel selects the circuits to be used. Dummy loads are automatically placed in both the current and volt circuits so that the external circuit not being measured is undisturbed.

The ability to "self-check" its own accuracy is of great value to any user of the instrument. We use zero temperature coefficient zener diodes to create the equivalent of a standard cell reference circuit which is internal battery operated. The reference voltage thus obtained is accurate to .01 percent.

There are lines on the scale to which the pointer is adjusted by internal rheostats by the user. This procedure only takes a few monments. When accomplished the engineer is assured that he has a precise instrument in his possession for immediate use.

We also have two small red colored binding posts on the instrument panel. When the pointer is correctly adjusted to full scale, there will appear 1 volt at these posts with an accuracy of .075 of 1%. The user can, if desired, use an outside potentiometer to verify the instrument's accuracy if there is ever a question of its internal check circuit and its .075 of 1% of full scale accuracy.

This 10" long vernier scale, very accurate multirange instrument will be a valuable asset to a progressive busy engineer or laboratory with its ability to self-check its own scale without its going back to the standards division.

SELF CHECKING
DIRECT CURRENT POLYRANGER
MODEL SCP

26 RANGES (FULL SCALE VALUES) — PRICE $725.00

50/100/200/500 Millivolts
1/2/5/10/20/50/100/200/500/1000 Volts
(1000 ohms per volt)
1/2/5/10/20/50/100/200/500 Milliamperes
1/2/5 Amperes

ACCURACY — (.075 of 1%) When self-checked at full scale
ACCURACY — (.15 of 1%) Overall accuracy
SCALE LENGTH — 10 inches
SCALE DIVISIONS — 100 (Vernier) type (see picture page 3)
RESOLUTION BY VERNIER TO .2 DIVISION
Can be readily interpolated to .1 DIVISION
SELF CHECKING
INTERNALLY SWITCHED — ACCOMPLISHED IN A FEW MOMENTS — INTERNAL BATTERY readily replaced from bottom of case
CASE — FORMICA (WALNUT) WITH REMOVABLE COVER
15⅞" x 10⅜" x 8"
INSTRUCTIONS — COMES WITH EACH POLYRANGER
APPROXIMATE WEIGHTS — 21 lbs. — Shipping 37 lbs.

ANNOUNCEMENT

We are always looking for new ideas that will advance the state of the intrument makers art.

If you have any undeveloped or completed ideas we would be very glad to correspond with you. We can, if required, undertake the industrial development of new measurement or allied products.

However, be warned that for your own protection you should not send in new, ingenious devices until you have obtained a patent or at least filed a patent application to protect yourself.

As this company has a very active R & D department we coincidentally could be working on an idea that might be similar to yours.

We wish to remain friends with one and all — THEREFORE — please drop us a line before you send specific details.

For over 30 years we have published this company bulletin "ELECTRICAL MEASUREMENTS." In it we describe new instruments and measurements techniques. It is sent without cost to interested persons.

If you have not been receiving this publication, please advise

SENSITIVE RESEARCH INSTRUMENT CORP.
310-316 Main Street
New Rochelle, New York, U.S.A.

SENSITIVE RESEARCH instruments are unconditionally guaranteed as to workmanship and materials for a period of one year. We guarantee our instruments to maintain their described accuracies, provided they are not abused and that the instrument seal is not broken.

Printed in U.S.A.

Prices and specifications subject to change without notice.

Sensi

DAYTON OHIO JUL 1 1962

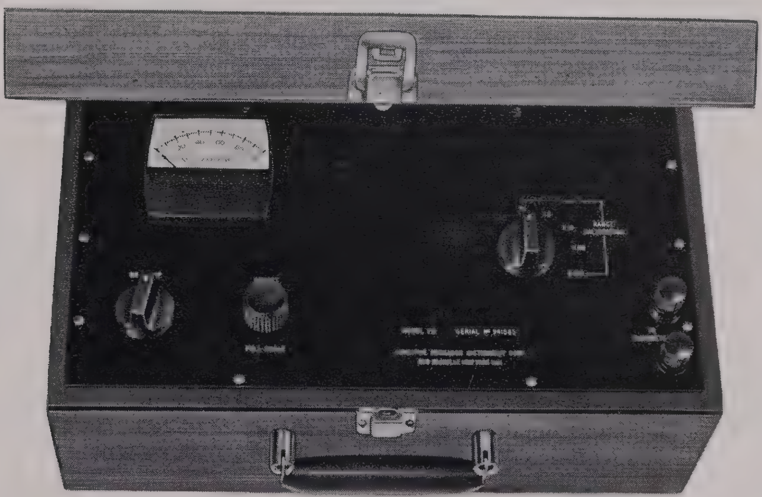
Electrical MEASUREMENTS

VOLUME 29 JUNE, 1962 NUMBER 6

SELF CHECKING!
10 INCH VERNIER D. C. POLYRANGER
and a
FLUXMETER CALIBRATOR

NEW!

MODEL FC



FLUXMETER CALIBRATOR
ACCURACY
.2 OF 1%

Our SENSITIVE RESEARCH FLUXMETER which we have built the past 35 years has an extremely versatile usage in magnetic measurements. Besides its basic use for the measurement of flux linkages, by means of a search coil, it is also used in many other applications where its ability to integrate voltage or current with time is of value.

Calibrations on these instruments are made in terms of milliampere seconds, of coulombs discharged through specific resistances, and many other methods. In the same manner that it is used in such a wide variety of applications it has also been calibrated in a wide variety of ways.

Calibration equipment for use with this instrument have included many different forms of mutual inductors in which a primary current was started, stopped or reversed to provide a known or calculable number of flux line changes in the secondary. Calibrations have also been performed using accurately monitored currents for known lengths of time. Calibrations of a fluxmeter have also been made by charging an accurately known capacitor to a specified voltage and using the discharge of this capacitor for calibration purposes. Standard magnets and search coils have also been used for 1 percent measurement.

The new Model FC Fluxmeter Calibrator being introduced by SRIC uses the mutual inductance calibration method. For high accuracy and long term stability mutual inductors with air cores have traditionally been used. However, when we start considering the design of a satisfactory air core mutual inductor for use in fluxmeter calibrations of an instrument with as wide ranges as the SENSITIVE RESEARCH Model FM, difficulties are encountered.

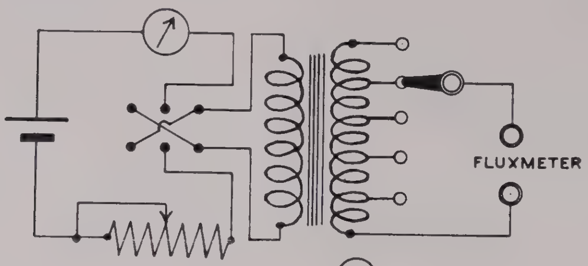
SENSITIVE RESEARCH
INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

Symbol of Quality

The secondary resistance must be kept to not more than 15 ohms, yet the total number of turns required is extremely high in order to produce a satisfactory value of mutual inductance to allow calibration of its X100 range with reasonable primary currents. This leads to impossibly large and expensive inductors. Thanks to wide spread development in the magnetic amplifier field, high permeability tape wound magnetic cores are available in "Square Loop" type materials. Full advantage of these specialized materials have been taken in the design of the Model FC.



①

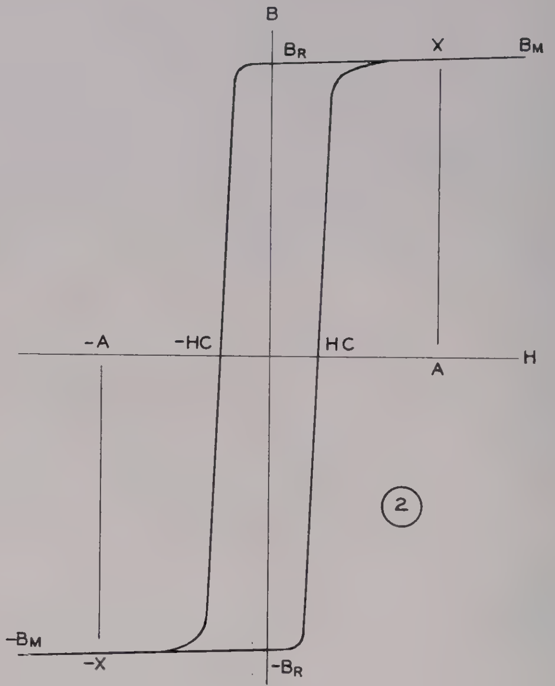
The basic circuit used is shown in figure 1. Current from an internal battery source is fed through an adjusting rheostat and a monitoring current meter, through a reversing switch to the primary of a transformer using a square loop type core material. A secondary with taps to adjust to an appropriate number of turns is used to sense the flux reversals in the core and these flux reversals constitute the calibration energy for the fluxmeter.

In figure 2 is shown a typical hyteresis loop for the type of core material used in the calibrator. It will be seen that once excitations slightly beyond the HC value are used that the values of Bmax is substantially stable regardless of variation in the value of H. For purposes of our calibrator a value of H is chosen at A. This allows the core to traverse the hysteresis loop from point X to —X or vice versa. For each complete reversal of the primary current it will be noticed that at the points the BH loop is, in effect, a single line and its slope is nearly, but not exactly, horizontal. This effect is taken advantage of in this calibrator. The fact that it is nearly horizontal means that if the primary current is measured to a relatively rough accuracy the total flux reversals will be very accurately determined.

Variations of ± 5% in the value of H (exciting current) will change total flux densitites by less than .05%. This lack of sensitivity to exciting current allows the use of a relatively small inexpensive indicating instrument and still maintain a high degree of calibration accuracy. However, the fact that the changes are present, even though small, allows for a very satisfactory adjustment of the final calibration point by moving the point X large amounts in either direction.

This can be done by either a change in meter sensitivity or a change in primary turns or a combination of both.

Due to the extremely high permeability of the core material, as soon as any one of the secondary tap points is adjusted satisfactory for its range all the others will automatically fall in line directly proportional to the number of turns involved. This is true to the extent that core permeability is higher than air, a factor of 40,000 to 1. In addition the coil design includes an extremely low primary — secondary capacitance to eliminate error from the conductance of this capacity.



②

The standard Model FC has appropriately proportioned tap points of the secondary to provide calibrations for each of the cardinal points on the standard Model FM Fluxmeter. In addition, it also provides a full scale point for each of the multiplier ranges. This allows a complete recertification of our fluxmeters on all ranges to a basic accuracy of .2 of 1% of any of the calibrating points. All of these various output ranges are made up to an exact 15 ohms for use in calibrating our FS and FM models. In addition, temperature compensation is applied to all ranges of the calibrator. The instrument is certified at a temperature of 25°C and will have a temperature coefficient not worse than .04% per degree C. This correction will be constant and linear, and will be marked on the calibration certificate furnished with the instrument. If operation at extremes of temperatures should be required the necessary correction factor can be readily applied.

Operation of the instrument is extremely simple. The fluxmeter is connected to the binding posts of the calibrator, the range switch set to the desired check point, the current is then adjusted by means of the rheostat to the red calibration line of the panel instrument, and one or two current reversals made with the panel reversing switch. The fluxmeter is then carefully zeroed and the reversing switch thrown. This will provide an output pulse which will bring the fluxmeter point to the exact value set. Complete instructions with calibrator.

MODEL FC
FLUXMETER CALIBRATOR

*PRICE $342.00

ACCURACY — .2 of 1 percent

RANGES — Full scale points for the X1, X3, X10, X30X100 ranges of the Model FM (SRIC Fluxmeter) AND the 10 - 20 - 30 - 40 - 50 division points on its X1 range only.

The above values are for standard 10000 lines per division instruments.

CASE — 13¾" x 7½" x 6½".

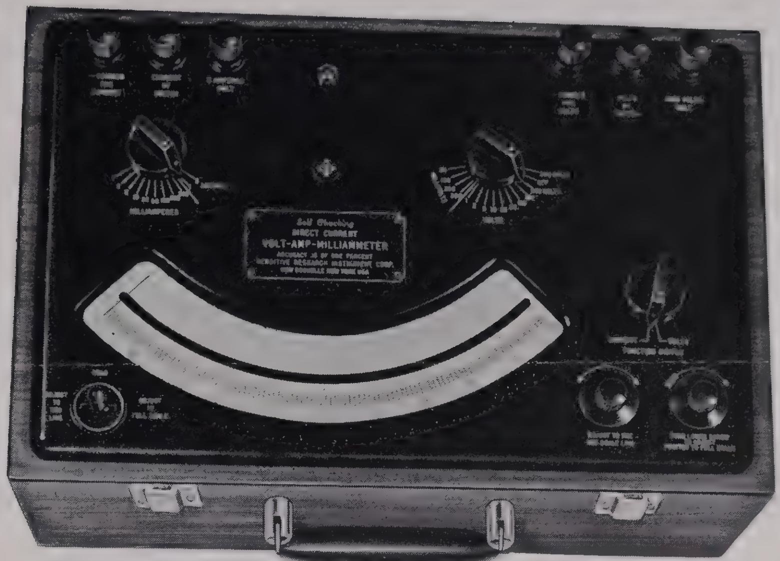
WEIGHTS — 12 lbs. Shipping 26 lbs.

POWER SUPPLY — 2 #RM-42R Mallory batteries or equal. (Replaced from back of case.)

* This calibrator can be supplied for rack mounting on a standard, 19" x 7" x ⅛" aluminum panel. (GRAY is standard.) Additional cost $50.00.

A "SELF CHECKING" 10 INCH VERNIER D.C. POLYRANGER

MODEL **SCP**



OVERALL
ACCURACY .15 OF 1%

Engineering design is always a continuing series of compromises. A matching of many contradictory design requirements to arrive at an optimum overall solution is the usual designer's headache. It seems that no sooner are these compromises made to a point where they seem sane and reasonable then some new technique crosses the horizon and requires a complete re-evaluation.

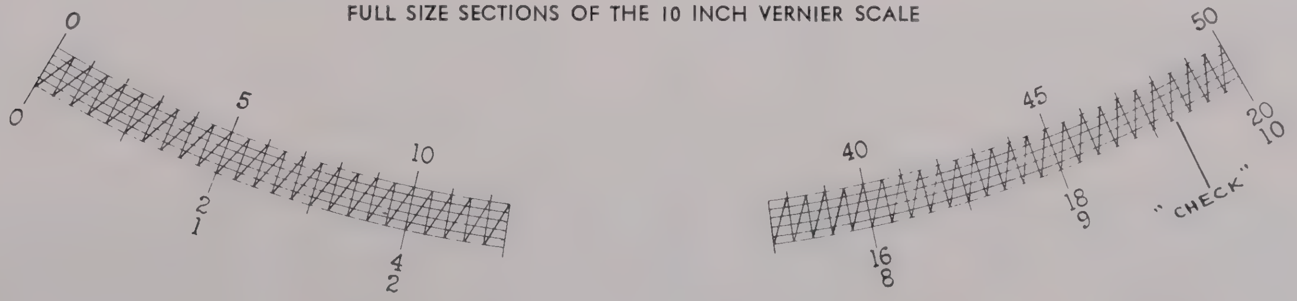
Many years ago, engineers arrived at an optimum portable panel instrument with something in the order of a 6" scale. A number of laboratory standard instruments were made with 12" scales; however, these were strictly limited in ranges and power consumed because of a relatively long, heavy pointer with correspondingly heavier moving parts.

SENSITIVE RESEARCH pioneered the use of "Self-Checking" circuits for improvement of the basic long term stability and accuracy of instruments. Because of these factors, we have worked ourselves into an engineering corner where the design compromises need to be re-evaluated.

Due to our improved ability to self-check instruments the long term stability and the basic accuracy of the instruments is so excellent that the actual readability of the scale becomes a LIMITING FACTOR. Rather than go to the 12" scale instrument with its realtively heavy massive moving system, it seems justified at this time to introduce an intermediate design.

Our new SRIC Model SCP 10 inch volt-amp-milliammeter is the first instrument embodying this compromise movement. The scale readability has been increased to a point where it is comparable with the actual accuracy of the instrument and yet the mechanical characteristics of the instrument are such that we can still operate with a very reasonable degree of sensitivity.

It would seem that this basic new instrument design might very well be the forerunner of many instruments which could take advantage of this somewhat new and different compromise in DC movement characteristics.



FULL SIZE SECTIONS OF THE 10 INCH VERNIER SCALE

Our original DC POLYRANGER was designed in 1927 as the first practical double pivoted Multirange Milliammeter-Voltmeter with a resistance as high as 10,000 ohms per volt. Since that time, the original design has been enlarged to include the world's finest selection of true poly-range instruments, both AC and DC.

Our POLYRANGER designs appeal to those discriminating people who want personal precision instruments, with which they can be assured of being able to measure accurately the various values of current or voltage essential to modern research.

This new Model SCP Direct Current POLYRANGER, with its 10 inch vernier scale has internal circuitry and a self contained battery to check its full scale points to within .075 of 1%. When adjusted and self-checked all the points on its 10 inch scale will be within .15 of 1% and its top point will be within .075 of 1%. This new POLYRANGER has 26 ranges. There are 14 ranges in volts and millivolts. The lowest range is 50 millivolts full scale. The highest is 1000 volts. (The 50 and 100 millivolt ranges are particularly well adapted for the use of external shunts.)

There are 12 current ranges from one milliampere full scale to 5 amperes full scale.

The Voltage and Current sections are COMPLETELY separated from each other. This means that both current and voltage can be applied to the Polyranger at the same time. A function switch on its panel selects the circuits to be used. Dummy loads are automatically placed in both the current and volt circuits so that the external circuit not being measured is undisturbed.

The ability to "self-check" its own accuracy is of great value to any user of the instrument. We use zero temperature coefficient zener diodes to create the equivalent of a standard cell reference circuit which is internal battery operated. The reference voltage thus obtained is accurate to .01 percent.

There are lines on the scale to which the pointer is adjusted by internal rheostats by the user. This procedure only takes a few monments. When accomplished the engineer is assured that he has a precise instrument in his possession for immediate use.

We also have two small red colored binding posts on the instrument panel. When the pointer is correctly adjusted to full scale, there will appear 1 volt at these posts with an accuracy of .075 of 1%. The user can, if desired, use an outside potentiometer to verify the instrument's accuracy if there is ever a question of its internal check circuit and its .075 of 1% of full scale accuracy.

This 10" long vernier scale, very accurate multirange instrument will be a valuable asset to a progressive busy engineer or laboratory with its ability to self-check its own scale without its going back to the standards division.

SELF CHECKING
DIRECT CURRENT POLYRANGER
MODEL SCP

26 RANGES (FULL SCALE VALUES) PRICE
  50/100/200/500 Millivolts $725.00
  1/2/5/10/20/50/100/200/500/1000 Volts
  (1000 ohms per volt)
  1/2/5/10/20/50/100/200/500 Milliamperes
  1/2/5 Amperes

ACCURACY — (.075 of 1%) When self-checked at full scale
ACCURACY — (.15 of 1%) Overall accuracy
SCALE LENGTH — 10 inches
SCALE DIVISIONS — 100 (Vernier) type (see picture page 3)
RESOLUTION BY VERNIER TO .2 DIVISION
  Can be readily interpolated to .1 DIVISION
SELF CHECKING
  INTERNALLY SWITCHED — ACCOMPLISHED IN A FEW MOMENTS — INTERNAL BATTERY readily replaced from bottom of case
CASE — FORMICA (WALNUT) WITH REMOVABLE COVER
  15⅞" x 10⅜" x 8"
INSTRUCTIONS — COMES WITH EACH POLYRANGER
APPROXIMATE WEIGHTS — 21 lbs. — Shipping 37 lbs.

* * *

ANNOUNCEMENT

We are always looking for new ideas that will advance the state of the intrument makers art.

If you have any undeveloped or completed ideas we would be very glad to correspond with you. We can, if required, undertake the industrial development of new measurement or allied products.

However, be warned that for your own protection you should not send in new, ingenious devices until you have obtained a patent or at least filed a patent application to protect yourself.

As this company has a very active R & D department we coincidentally could be working on an idea that might be similar to yours.

We wish to remain friends with one and all — THEREFORE — please drop us a line before you send specific details.

For over 30 years we have published this company bulletin "ELECTRICAL MEASUREMENTS." In it we describe new instruments and measurements techniques. It is sent without cost to interested persons.

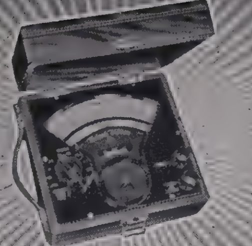
If you have not been receiving this publication, please advise

SENSITIVE RESEARCH INSTRUMENT CORP.
310-316 Main Street
New Rochelle, New York, U.S.A.

SENSITIVE RESEARCH instruments are unconditionally guaranteed as to workmanship and materials for a period of one year. We guarantee our instruments to maintain their described accuracies, provided they are not abused and that the instrument seal is not broken.

Printed in U.S.A.

Prices and specifications subject to change without notice.



Electrical MEASUREMENTS

VOLUME 29 JUNE, 1962 NUMBER 6

SELF CHECKING!

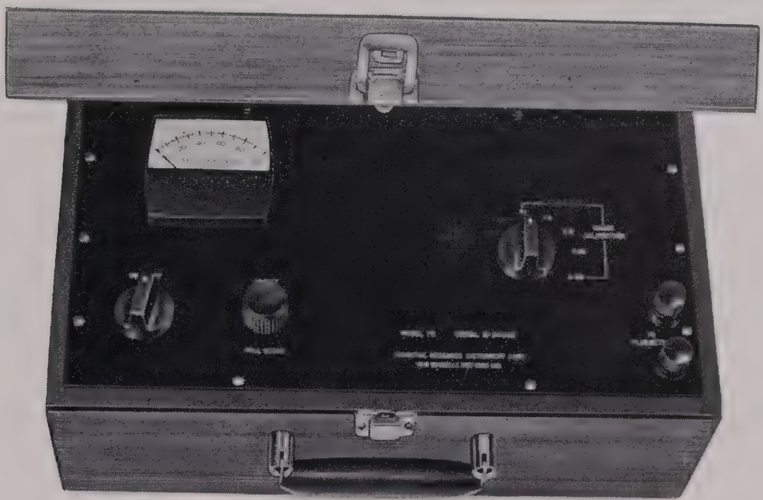
10 INCH VERNIER D. C. POLYRANGER

and a

FLUXMETER CALIBRATOR

NEW!

MODEL FC



FLUXMETER CALIBRATOR
ACCURACY
.2 OF 1%

Our SENSITIVE RESEARCH FLUXMETER which we have built the past 35 years has an extremely versatile usage in magnetic measurements. Besides its basic use for the measurement of flux linkages, by means of a search coil, it is also used in many other applications where its ability to integrate voltage or current with time is of value.

Calibrations on these instruments are made in terms of milliampere seconds, of coulombs discharged through specific resistances, and many other methods. In the same manner that it is used in such a wide variety of applications it has also been calibrated in a wide variety of ways.

Calibration equipment for use with this instrument have included many different forms of mutual inductors in which a primary current was started, stopped or reversed to provide a known or calculable number of flux line changes in the secondary. Calibrations have also been performed using accurately monitored currents for known lengths of time. Calibrations of a fluxmeter have also been made by charging an accurately known capacitor to a specified voltage and using the discharge of this capacitor for calibration purposes. Standard magnets and search coils have also been used for 1 percent measurement.

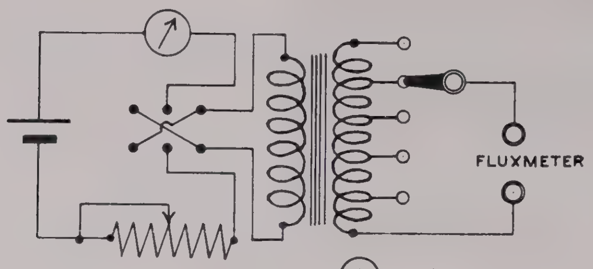
The new Model FC Fluxmeter Calibrator being introduced by SRIC uses the mutual inductance calibration method. For high accuracy and long term stability mutual inductors with air cores have traditionally been used. However, when we start considering the design of a satisfactory air core mutual inductor for use in fluxmeter calibrations of an instrument with as wide ranges as the SENSITIVE RESEARCH Model FM, difficulties are encountered.

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y. *ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927*

S
Symbol of Quality

The secondary resistance must be kept to not more than 15 ohms, yet the total number of turns required is extremely high in order to produce a satisfactory value of mutual inductance to allow calibration of its X100 range with reasonable primary currents. This leads to impossibly large and expensive inductors. Thanks to wide spread development in the magnetic amplifier field, high permeability tape wound magnetic cores are available in "Square Loop" type materials. Full advantage of these specialized materials have been taken in the design of the Model FC.



①

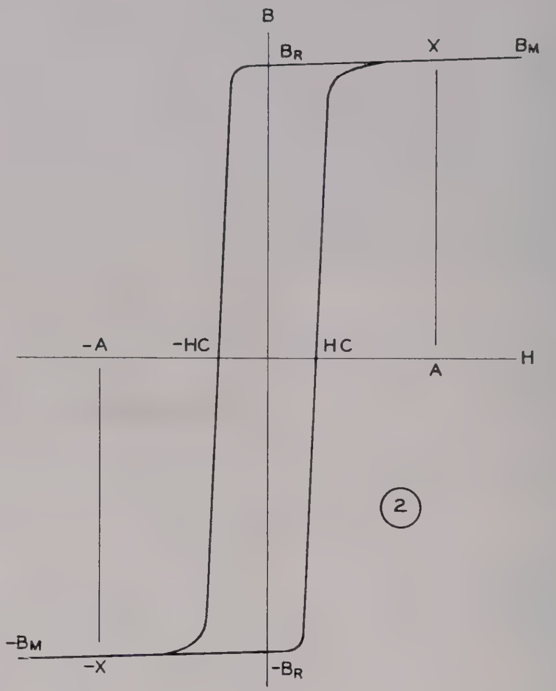
The basic circuit used is shown in figure 1. Current from an internal battery source is fed through an adjusting rheostat and a monitoring current meter, through a reversing switch to the primary of a transformer using a square loop type core material. A secondary with taps to adjust to an appropriate number of turns is used to sense the flux reversals in the core and these flux reversals constitute the calibration energy for the fluxmeter.

In figure 2 is shown a typical hyteresis loop for the type of core material used in the calibrator. It will be seen that once excitations slightly beyond the HC value are used that the values of Bmax is substantially stable regardless of variation in the value of H. For purposes of our calibrator a value of H is chosen at A. This allows the core to traverse the hysteresis loop from point X to —X or vice versa. For each complete reversal of the primary current it will be noticed that at the points the BH loop is, in effect, a single line and its slope is nearly, but not exactly, horizontal. This effect is taken advantage of in this calibrator. The fact that it is nearly horizontal means that if the primary current is measured to a relatively rough accuracy the total flux reversals will be very accurately determined.

Variations of ± 5% in the value of H (exciting current) will change total flux densitites by less than .05%. This lack of sensitivity to exciting current allows the use of a relatively small inexpensive indicating instrument and still maintain a high degree of calibration accuracy. However, the fact that the changes are present, even though small, allows for a very satisfactory adjustment of the final calibration point by moving the point X large amounts in either direction.

This can be done by either a change in meter sensitivity or a change in primary turns or a combination of both.

Due to the extremely high permeability of the core material, as soon as any one of the secondary tap points is adjusted satisfactory for its range all the others will automatically fall in line directly proportional to the number of turns involved. This is true to the extent that core permeability is higher than air, a factor of 40,000 to 1. In addition the coil design includes an extremely low primary — secondary capacitance to eliminate error from the conductance of this capacity.



②

The standard Model FC has appropriately proportioned tap points of the secondary to provide calibrations for each of the cardinal points on the standard Model FM Fluxmeter. In addition, it also provides a full scale point for each of the multiplier ranges. This allows a complete recertification of our fluxmeters on all ranges to a basic accuracy of .2 of 1% of any of the calibrating points. All of these various output ranges are made up to an exact 15 ohms for use in calibrating our FS and FM models. In addition, temperature compensation is applied to all ranges of the calibrator. The instrument is certified at a temperature of 25°C and will have a temperature coefficient not worse than .04% per degree C. This correction will be constant and linear, and will be marked on the calibration certificate furnished with the instrument. If operation at extremes of temperatures should be required the necessary correction factor can be readily applied.

Operation of the instrument is extremely simple. The fluxmeter is connected to the binding posts of the calibrator, the range switch set to the desired check point, the current is then adjusted by means of the rheostat to the red calibration line of the panel instrument, and one or two current reversals made with the panel reversing switch. The fluxmeter is then carefully zeroed and the reversing switch thrown. This will provide an output pulse which will bring the fluxmeter point to the exact value set. Complete instructions with calibrator.

MODEL FC
FLUXMETER CALIBRATOR

*PRICE $342.00

ACCURACY — .2 of 1 percent

RANGES — Full scale points for the X1, X3, X10, X30X100 ranges of the Model FM (SRIC Fluxmeter) AND the 10 - 20 - 30 - 40 - 50 division points on its X1 range only.

The above values are for standard 10000 lines per division instruments.

CASE — 13¾" x 7½" x 6½".

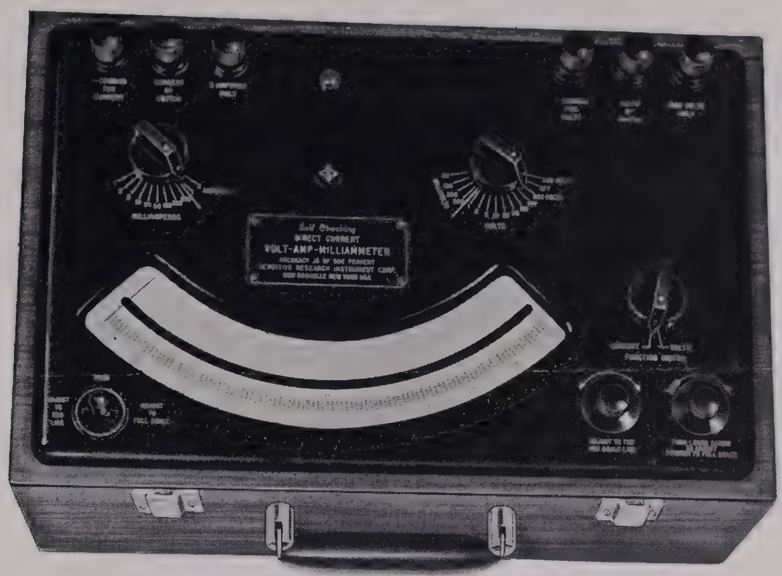
WEIGHTS — 12 lbs. Shipping 26 lbs.

POWER SUPPLY — 2 #RM–42R Mallory batteries or equal. (Replaced from back of case.)

* This calibrator can be supplied for rack mounting on a standard, 19" x 7" x ⅛" aluminum panel. (GRAY is standard.) Additional cost $50.00.

A "SELF CHECKING" 10 INCH VERNIER D.C. POLYRANGER

MODEL **SCP**



OVERALL
ACCURACY .15 OF 1%

Engineering design is always a continuing series of compromises. A matching of many contradictory design requirements to arrive at an optimum overall solution is the usual designer's headache. It seems that no sooner are these compromises made to a point where they seem sane and reasonable then some new technique crosses the horizon and requires a complete re-evaluation.

Many years ago, engineers arrived at an optimum portable panel instrument with something in the order of a 6" scale. A number of laboratory standard instruments were made with 12" scales; however, these were strictly limited in ranges and power consumed because of a relatively long, heavy pointer with correspondingly heavier moving parts.

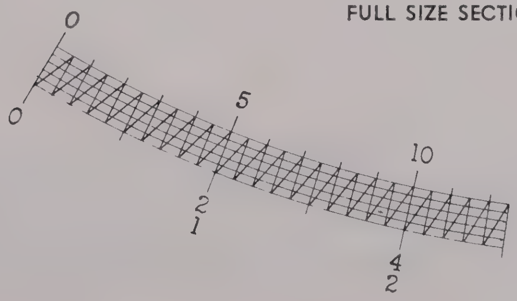
SENSITIVE RESEARCH pioneered the use of "Self-Checking" circuits for improvement of the basic long term stability and accuracy of instruments. Because of these factors, we have worked ourselves into an engineering corner where the design compromises need to be re-evaluated.

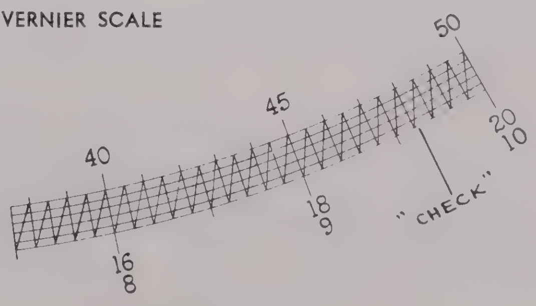
Due to our improved ability to self-check instruments the long term stability and the basic accuracy of the instruments is so excellent that the actual readability of the scale becomes a LIMITING FACTOR. Rather than go to the 12" scale instrument with its realtively heavy massive moving system, it seems justified at this time to introduce an intermediate design.

Our new SRIC Model SCP 10 inch volt-amp-milliammeter is the first instrument embodying this compromise movement. The scale readability has been increased to a point where it is comparable with the actual accuracy of the instrument and yet the mechanical characteristics of the instrument are such that we can still operate with a very reasonable degree of sensitivity.

It would seem that this basic new instrument design might very well be the forerunner of many instruments which could take advantage of this somewhat new and different compromise in DC movement characteristics.

FULL SIZE SECTIONS OF THE 10 INCH VERNIER SCALE





...MEASUREMENT IS THE BASIS OF PROGRESS...

Our original DC POLYRANGER was designed in 1927 as the first practical double pivoted Multirange Milliammeter-Voltmeter with a resistance as high as 10,000 ohms per volt. Since that time, the original design has been enlarged to include the world's finest selection of true poly-range instruments, both AC and DC.

Our POLYRANGER designs appeal to those discriminating people who want personal precision instruments, with which they can be assured of being able to measure accurately the various values of current or voltage essential to modern research.

This new Model SCP Direct Current POLYRANGER, with its 10 inch vernier scale has internal circuitry and a self contained battery to check its full scale points to within .075 of 1%. When adjusted and self-checked all the points on its 10 inch scale will be within .15 of 1% and its top point will be within .075 of 1%. This new POLYRANGER has 26 ranges. There are 14 ranges in volts and millivolts. The lowest range is 50 millivolts full scale. The highest is 1000 volts. (The 50 and 100 millivolt ranges are particularly well adapted for the use of external shunts.)

There are 12 current ranges from one milliampere full scale to 5 amperes full scale.

The Voltage and Current sections are COMPLETELY separated from each other. This means that both current and voltage can be applied to the Polyranger at the same time. A function switch on its panel selects the circuits to be used. Dummy loads are automatically placed in both the current and volt circuits so that the external circuit not being measured is undisturbed.

The ability to "self-check" its own accuracy is of great value to any user of the instrument. We use zero temperature coefficient zener diodes to create the equivalent of a standard cell reference circuit which is internal battery operated. The reference voltage thus obtained is accurate to .01 percent.

There are lines on the scale to which the pointer is adjusted by internal rheostats by the user. This procedure only takes a few monments. When accomplished the engineer is assured that he has a precise instrument in his possession for immediate use.

We also have two small red colored binding posts on the instrument panel. When the pointer is correctly adjusted to full scale, there will appear 1 volt at these posts with an accuracy of .075 of 1%. The user can, if desired, use an outside potentiometer to verify the instrument's accuracy if there is ever a question of its internal check circuit and its .075 of 1% of full scale accuracy.

This 10" long vernier scale, very accurate multirange instrument will be a valuable asset to a progressive busy engineer or laboratory with its ability to self-check its own scale without its going back to the standards division.

SELF CHECKING
DIRECT CURRENT POLYRANGER
MODEL SCP

26 RANGES (FULL SCALE VALUES)	PRICE
50/100/200/500 Millivolts 1/2/5/10/20/50/100/200/500/1000 Volts (1000 ohms per volt) 1/2/5/10/20/50/100/200/500 Milliamperes 1/2/5 Amperes	$725.00

ACCURACY — (.075 of 1%) When self-checked at full scale
ACCURACY — (.15 of 1%) Overall accuracy
SCALE LENGTH — 10 inches
SCALE DIVISIONS — 100 (Vernier) type (see picture page 3)
RESOLUTION BY VERNIER TO .2 DIVISION
  Can be readily interpolated to .1 DIVISION
SELF CHECKING
  INTERNALLY SWITCHED — ACCOMPLISHED IN A FEW MOMENTS — INTERNAL BATTERY readily replaced from bottom of case
CASE — FORMICA (WALNUT) WITH REMOVABLE COVER
  15⅞" x 10⅜" x 8"
INSTRUCTIONS — COMES WITH EACH POLYRANGER
APPROXIMATE WEIGHTS — 21 lbs. — Shipping 37 lbs.

* * *

ANNOUNCEMENT

We are always looking for new ideas that will advance the state of the intrument makers art.

If you have any undeveloped or completed ideas we would be very glad to correspond with you. We can, if required, undertake the industrial development of new measurement or allied products.

However, be warned that for your own protection you should not send in new, ingenious devices until you have obtained a patent or at least filed a patent application to protect yourself.

As this company has a very active R & D department we coincidentally could be working on an idea that might be similar to yours.

We wish to remain friends with one and all — THEREFORE — please drop us a line before you send specific details.

For over 30 years we have published this company bulletin "ELECTRICAL MEASUREMENTS." In it we describe new instruments and measurements techniques. It is sent without cost to interested persons.

If you have not been receiving this publication, please advise

SENSITIVE RESEARCH INSTRUMENT CORP.
310-316 Main Street
New Rochelle, New York, U.S.A.

SENSITIVE RESEARCH instruments are unconditionally guaranteed as to workmanship and materials for a period of one year. We guarantee our instruments to maintain their described accuracies, provided they are not abused and that the instrument seal is not broken.

Printed in U.S.A.

Prices and specifications subject to change without notice.

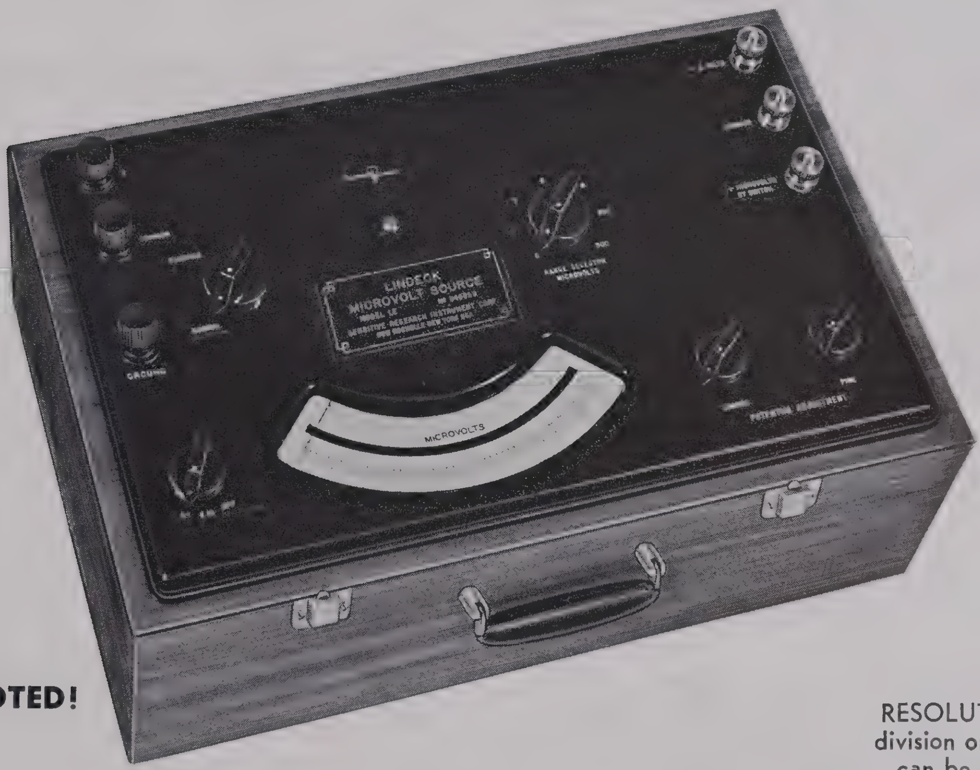
Electrical
MEASUREMENTS

VOLUME 29 APRIL, 1962 NUMBER 4

JUL 17 1962

THE NEW LINDECK MICROVOLT SOURCE

ACCURACY ± (.5 of 1% of full scale + .05μv.)


LINDECK
MICROVOLT SOURCE
MODEL LE
SENSITIVE RESEARCH INSTRUMENT CORP.
NEW ROCHELLE NEW YORK U.S.A.
RANGE SELECTOR
MICROVOLTS
MICROVOLTS
GROUND
POTENTIAL ADJUSTMENT

MODEL LE

DIAMOND PIVOTED!

RESOLUTION .01μv. per
division on the 1μv. range
can be interpolated if
required to .001μv.

The LINDECK element, as a source of highly accurate, very low microvolt potentials, has been in use since about 1899. A potentiometer, utilizing this principle, was first described by Lindeck and Rothe in that year. It was designed at that time primarily for the measurement of thermocouple EMF's.

It made use of a four terminal manganin resistance. The drop across this resistance was opposed to the unknown EMF in series with a galvanometer. The current through the resistor was adjustable by means of a separate rheostat and its value was read at balance by means of a milliammeter.

**SENSITIVE RESEARCH
INSTRUMENT CORPORATION**

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

Symbol of Quality

The basic circuit of the LINDECK element in the Sensitive Research microvolt source is shown in figure 1.

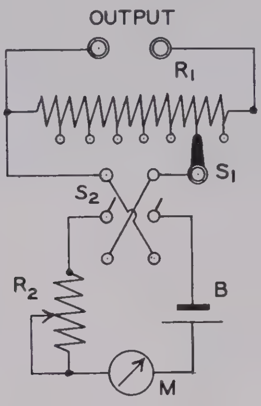


Figure 1

R_1 in this circuit, is a highly accurate and stable resistance. Switch S_1 provides a means for introducing a current into appropriate portions of R_1. The current is fed into the desired portion of R_1 from the battery B. The rheostat R_2, the polarity reversing switch S_2 and the milliammeter M provide means for adjusting and measuring the current in use.

Knowing the value of R_1 and the current indicated by the meter M, the exact microvolt output provided by this combination can be readily determined. In the Sensitive Research model LE microvolt source, these values for R_1 and M have been chosen so that the full scale reading of the milliammeter will provide microvolt values at the output from a low of 1 microvolt to a high of 5000 microvolts. This wide range is divided into a series of steps as follows: 0 - 1/2/5/100/200/500 microvolts.

These ranges are obtained by switching appropriate values of resistance by means of switch S_1. In addition the sensitivity of meter M is changed from a base range of 1 millampere to a range of 10 milliamperes by means of a panel switch marked X1 and X10.

The ten milliampere range multiplies the main range switch by a factor of ten to give a complete coverage on a 1, 2 and 5 basis from 1 microvolt to 5000 microvolts. A separate binding post gives a still higher output of .2 volt with the instrument measuring 1 milliampere and 2 volts with the milliammeter M in the X10 position.

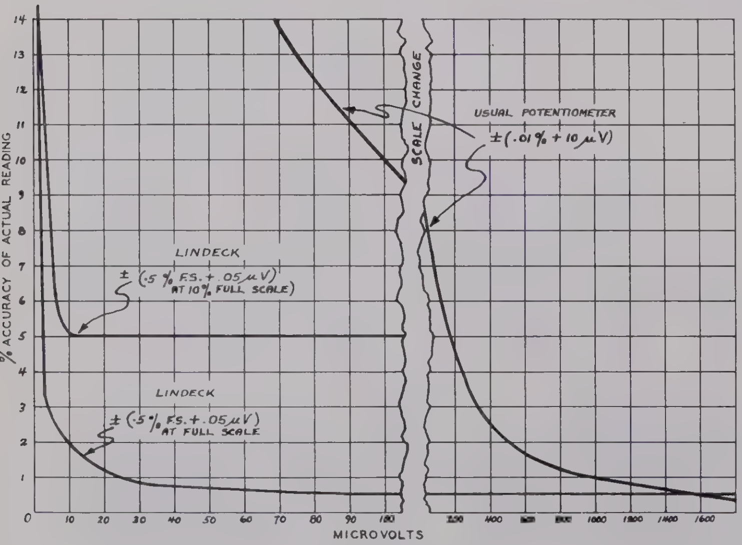


Figure 2

The resistance values of R_1 are adjusted to be accurate within .1%. The instrument M is our well known model C with an accuracy of .25%. This combination of accuracies can reasonably be expected to give an overall .35 of 1% accuracy and the model LE is actually guaranteed at a very conservative .5 of 1% full scale value.

This accuracy specification of .5 of 1% is WELL WORTH A SECOND LOOK. A direct comparison of the accuracies of such a LINDECK microvolt source with an ordinary .01% accurate potentiometer becomes very enlightening. The usual type of .01% potentiometer will have combined zero and thermal errors in the order of 10 to 20 microvolts. For purposes of comparison let us be reasonably conservative and say that the accuracy statement is ± (.01% of reading + 10 microvolts). This is to be compared with the accuracy statement for the Sensitive Research LINDECK Microvolt Source which is ± (.5% of full scale + .05 microvolt). In figure 2 we have shown comparative plots of these two accuracies in the low microvolt region. Because the LINDECK microvolt source varies in accuracy depending upon the scale position at which the pointer is being read, we are shown two different accuracy curves — one for full scale values and the other for values down at 1/10 of full scale. This is very much lower than is ever required except on the most sensitive range. It is readily seen that even at this reduced accuracy level the LINDECK type instrument becomes markedly better than the average potentiometer for the measurement of very low microvolt values.

This inherent ability to achieve a very low value of extraneous thermal EMFs and zero error, stems from the fact that there are no variable contacts any place in the microvolt circuit. Figure 1 shows plainly that directly across the output terminals there is only a very low and fixed value of resistance in the form of R_1. There are no switch contacts or slide wires or any other possible variable source of EMFs. Any contact potentials or variables in switches S_1 or S_2 do not contribute to errors in the output. They appear as merely variations in the battery B, and any variation stemming from this source will be included in the basic reading of instrument M.

The main advantage of the LINDECK type element is, of course, in the relative low microvolt ranges. However, as a matter of convenience, many higher ranges have been included in our model LE. This avoids the inconvenience of having to change equipment to a conventional type potentiometer when higher ranges are required at lesser accuracies. An additional convenient feature provided in the Sensitive Research version of the LINDECK microvolt source, is a very convenient means of self-checking the accuracy of the circuit.

A pair of external binding posts and an additional 5 ampere range on the instrument M provide a ready means of checking the calibration of resistors R_1. The resistors, which comprise R_1 are of very low value and are made to handle currents of at least 5 amperes without appreciable change in their characteristics. At this increased current the output voltages of the model LE are increased by a factor of 5000 to 1 over the normal X1 position.

At this level the output can readily be checked by an ordinary potentiometer to insure a satisfactory degree of over-all accuracy. This check is readily accomplished by providing an external source of adjustable 5 ampere current. An ordinary potentiometer is connected across the output terminals of the LINDECK and actual output values read. For full scale of the instrument M these values should be exactly 5000 times the engraved switch positions.

GENERAL OPERATION

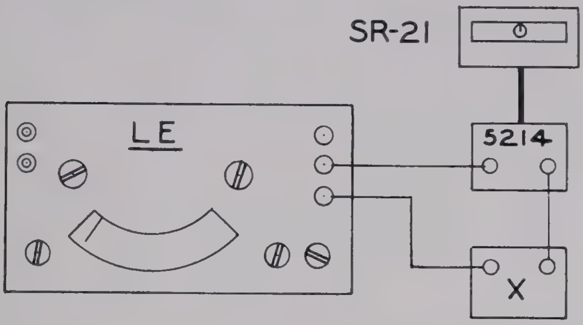
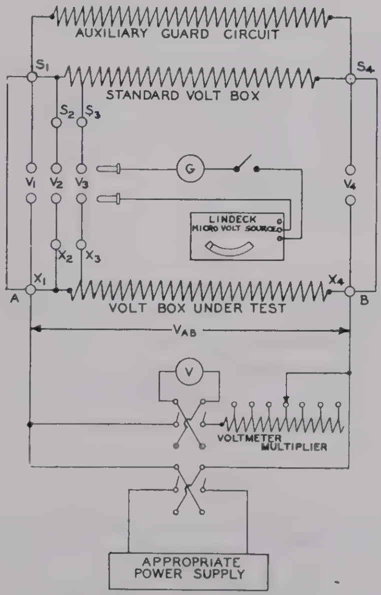


Figure 3

Figure 3 shows the general connection for the use of the model LE for the measurement of a source of microvolt potentials shown as the block box marked X. The diagram shows the instrument connected with a model 5214 Commander galvanometer amplifier and the output of the amplifier fed to a Commander SR 21 galvanometer (See our general catalog). The operation of the model LE is to cause it to produce an equal and opposite microvolt source in order to bring the SR 21 galvanometer to zero. This is done by selecting an appropriate range of voltage by means of the range selector and the X1, X10 range switch. The coarse and fine potential adjustment knobs are adjusted until the SR 21 indicates zero deflection. When this null is obtained, the value of microvolts appearing at the terminals of the LINDECK is determined by reading the scale of the instrument, the range selector and the X1, X10 range switch. These controls will give the value of the voltage appearing and the normal-reverse switch will show the polarity of this voltage, the normal position giving a polarity at the binding posts as indicated by the panel engraving.



VOLT BOX COMPARISON CIRCUIT

Figure 4

USE OF THE MODEL LE FOR INTERCOMPARISON OF VOLT BOXES

The LINDECK microvolt source provides one of the simplest and easiest methods for certifying a volt box against another standard volt box. The two boxes are connected in parallel across the power supply as shown in figure 4. An auxiliary guard circuit is shown on the standard volt box. This guard circuit is normally supplied in the highest accuracy type of volt boxes such as the Commander 9700 and 9700A. However, it is not required for this method of intercomparison except with such high accuracy instruments.

The voltage AB is adjusted by means of the power supply and the voltmeter V to the nominal value at which it is desired to intercompare the volt boxes. The 2 volt range of the model LE can be used with the normal output connection of the standard volt box to set the test voltage to approximate value. This eliminates the need for voltmeter V for setting the power supply voltage. The power supply does not have to be held accurately to this voltage, but merely to a stable value during the period of test. The voltages V_1, V_2, V_3 and V_4 are measured by the LINDECK microvolt source by adjusting it in each position to indicate zero on the galvanometer G. This galvanometer must have sufficient sensitivity to detect voltages of 1 or 2 microvolts. The Commander 5214 with its associated SR 21 galvanometer is recommended. However, with slightly less accuracy the model SR 4 Commander galvanometer can be substituted.

The correct ratio of the volt box under test will then be

$$R = R_S\ (1 + [(V_4 - V_1)/V_{AB}] - R_S\ [(V_3 - V_2)/V_{AB}]).$$

The above neglects second order and higher terms in the equation. The readings of the four values V_1, V_2, V_3 and V_4 are taken for all of the volt ratios at which the boxes are to be intercompared and corrections made for any known error with the standard volt box. The voltages V_1, V_2 and V_4 will usually be very small values compared to V_3 as they depend only on the resistance of connecting leads. The taking of these lead values can be ignored when measurements of lower accuracy are satisfactory. In this case the formula simplifies to $R_X = R_S\ (1 - F_S\ [\ V_S/V_{AB}])$.

INTERCOMPARISON OF STANDARD CELLS

The model LE microvolt source provides an excellent means of intercomparing standard cells to a very high degree of accuracy. The two standard cells to be compared are connected as shown in figure 5.

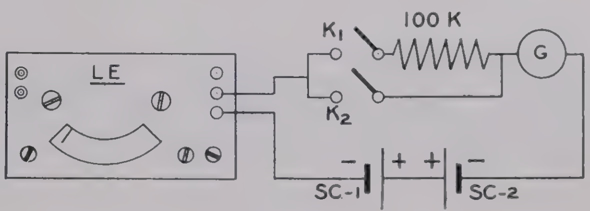


Figure 5

Once again the galvanometer G must be sufficiently sensitive to be able to detect fractional microvolt differences between the cells. The output of the LINDECK element is adjusted until zero galvanometer deflection is obtained when the keys are depressed.

In this standard cell measurement it is extremely important that the balance always be first obtained by means of the key 1, and that key 2 is not depressed until first a balance is obtained with key 1. In the event that there is a complete open or short circuit on either the unkown or the standard cell, this procedure will prevent damage to the standard. The reading of the LINDECK microvolt source will of course represent the difference between the value of SC 1, the standard, and SC 2, the cell under test. Addition or subtraction from the known value of the standard will be required to obtain the actual value of the unknown standard cell. Our Commander galvanometer amplifier model 5214 and the SR 21 are once again the recommended units for use as galvanometer G in figure 5; the SR 4 galvanometer can be substituted at a reduced accuracy.

GENERAL PRECAUTIONS REQUIRED

Measurement operations in the very low microvolt range require many careful techniques not ordinarily encountered. The avoidance of undesired thermal voltages comparable in magnitude to those being measured is very difficult in the low microvolt range where the LINDECK element is most used. For utmost accuracy it is almost an absolute requirement that measurements be made in a TEMPERATURE CONTROLLED AREA.

Further, all the instruments being measured should be allowed to stabilize at the temperature for a period of MANY HOURS before measurements are attempted. All connections between elements must be made with BARE (NOT TINNED) THINLY INSULATED COPPER WIRE. A good portion of the leads should be carefully wrapped around the copper binding post to insure good thermal contact. The galvanometer keys should be of a very low thermal type as ordinary types of galvanometer keys would themselves introduce thermals sufficiently large to give gross errors.

The Commander number 9145 low thermal switch is recommended for this application. Protective resistors in circuits such as the 100K shown in figure 5 should be of a stable wire wound type even though the accuracy does not enter into the overall measurement. Some types of composition resistors used in these applications provide relatively large extraneous voltages which are difficult to compensate or calculate.

The LINDECK microvolt source is many times used to determine residual thermals in apparatus that are of very low magnitude. Ordinarily this is accomplished with the circuit shown in figure 3. In this case the model LE combined with a 5214 galvanometer amplifier and the SR 21 galvanometer are being used to measure thermals in the block box X. All connections have been made with bare (un-tinned) thinly insulated copper wire, all of the gear has been in an air conditioned temperature controlled room for a period of many hours to reach overall stability.

If now the controls of the model LE are adjusted for balance on the SR 21 galvanometer a reading of voltage will be obtained. This reading will be the desired voltage originating in equipment X. It will also, however, include extraneous voltages from the wiring, from the 5214 and from the model LE itself.

After this first reading is taken, all connections should be left as shown in the diagram, and in addition a direct short placed across the equipment X. This short can best be in the form of a copper bar directly across the terminals involved. A second reading should be taken after this direct short is placed in position. As a matter of fact, the reading should be taken several minutes after the bar is in place because of possible thermal effects from your hand in connecting the bar.

This second reading will be that of all the extraneous EMF's other than the desired voltages originating in equipment X. This reading should be subtracted from the first reading. For utmost accuracy both readings should be taken several times to eliminate any possibility of slow drifts in any of the minute voltages invovled.

The average of such a group of readings will very closely approximate the actual value. Under these conditions readings to as low as .01 microvolt can be accomplished with a fair degree of reliability if extreme care is used.

If the user is not very familiar with the difficulties in taking measurements in the low microvolt region, it is suggested that set-ups similar to those shown in figure 3 be made and the effects of touching one of the terminals, of slight air currents, the use of tinned copper vs. bare copper wire and similar sources of difficulty be examined.

This will be an extremely enlightening experience for one not familiar with operations in this area of voltage. If due account is taken of all the error possibilities in this type of measurement excellent accuracies are obtainable. Without these rather slow painstaking techniques, measurements are of very little value.

LINDECK MICROVOLT SOURCE

ACCURACY
± (.5% of full scale + .05μv.)

READOUT INSTRUMENT
Accuracy .25%
Scale Length 6.3"
100 Divisions
Diamond Pivoted

RESOLUTION — CODE LINDECK
.01μv./Division on 1μv. Range
Instrument can be interpolated to
tenths of 1 division or .001μv.

SELF CHECKING
Requires only a 5 ampere source
and an external potentiometer.

CASE
Formica 15⅞" x 10⅜" x 8"

APPROX. WEIGHT
21 lbs — Shipping 43 lbs.

RANGES — PRICE
0 - 1/2/5/10/20/50/100/200/500 microvolts & 1/2/5/200 millivolts & 2 volts — $565.00

◆

For over 29 years we have published this company bulletin "ELECTRICAL MEASUREMENTS." In it we describe new instruments and measurement techniques. It is sent without cost to interested persons. If you have not been receiving this publication, please advise SENSITIVE RESEARCH."

Printed in U.S.A.

Prices and specifications subject
to change without notice.

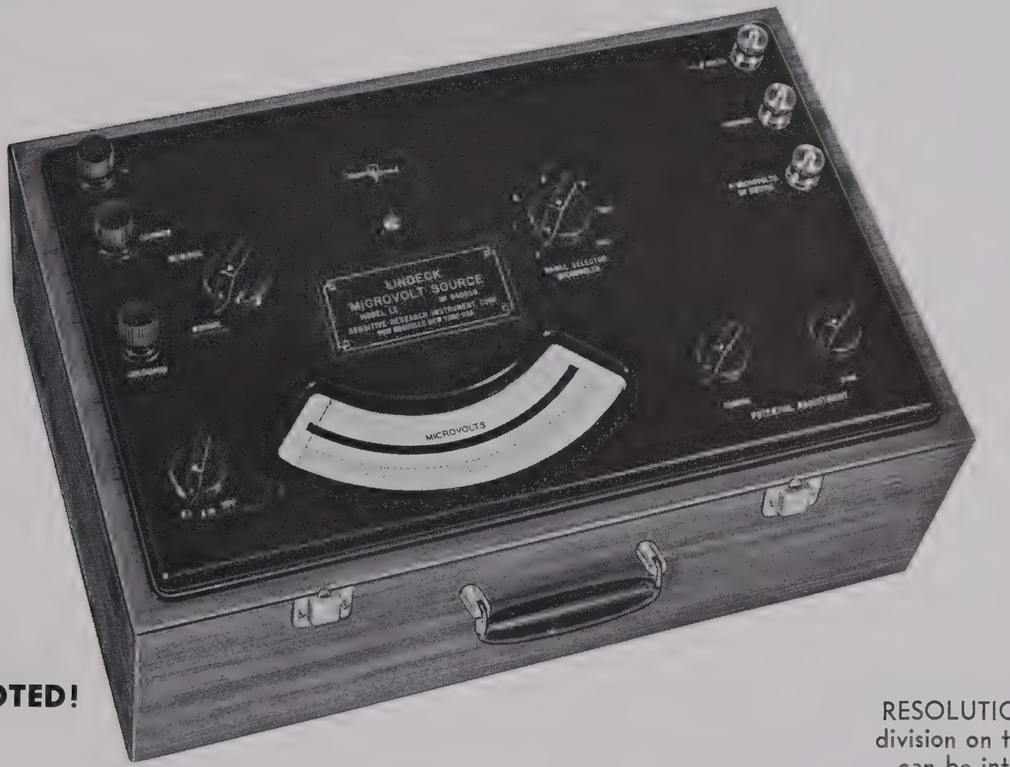
Electrical MEASUREMENTS

JUL 17 1962

VOLUME 29 APRIL, 1962 NUMBER 4

THE NEW LINDECK MICROVOLT SOURCE

ACCURACY ± (.5 of 1% of full scale + .05μv.)


LINDECK
MICROVOLT SOURCE
MODEL LE
SENSITIVE RESEARCH INSTRUMENT CORP.
NEW ROCHELLE NEW YORK USA
MICROVOLTS

MODEL **LE**

DIAMOND PIVOTED!

RESOLUTION .01μv. per
division on the 1μv. range
can be interpolated if
required to .001μv.

The LINDECK element, as a source of highly accurate, very low microvolt potentials, has been in use since about 1899. A potentiometer, utilizing this principle, was first described by Lindeck and Rothe in that year. It was designed at that time primarily for the measurement of thermocouple EMF's.

It made use of a four terminal manganin resistance. The drop across this resistance was opposed to the unknown EMF in series with a galvanometer. The current through the resistor was adjustable by means of a separate rheostat and its value was read at balance by means of a milliammeter.

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

S

Symbol of Quality

The basic circuit of the LINDECK element in the Sensitive Research microvolt source is shown in figure 1.

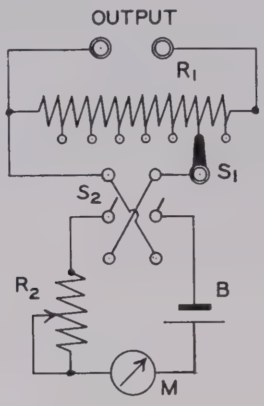


Figure 1

R_1 in this circuit, is a highly accurate and stable resistance. Switch S_1 provides a means for introducing a current into appropriate portions of R_1. The current is fed into the desired portion of R_1 from the battery B. The rheostat R_2, the polarity reversing switch S_2 and the milliammeter M provide means for adjusting and measuring the current in use.

Knowing the value of R_1 and the current indicated by the meter M, the exact microvolt output provided by this combination can be readily determined. In the Sensitive Research model LE microvolt source, these values for R_1 and M have been chosen so that the full scale reading of the milliammeter will provide microvolt values at the output from a low of 1 microvolt to a high of 5000 microvolts. This wide range is divided into a series of steps as follows: 0 - 1/2/5/100/200/500 microvolts.

These ranges are obtained by switching appropriate values of resistance by means of switch S_1. In addition the sensitivity of meter M is changed from a base range of 1 millampere to a range of 10 milliamperes by means of a panel switch marked X1 and X10.

The ten milliampere range multiplies the main range switch by a factor of ten to give a complete coverage on a 1, 2 and 5 basis from 1 microvolt to 5000 microvolts. A separate binding post gives a still higher output of .2 volt with the instrument measuring 1 milliampere and 2 volts with the milliammeter M in the X10 position.

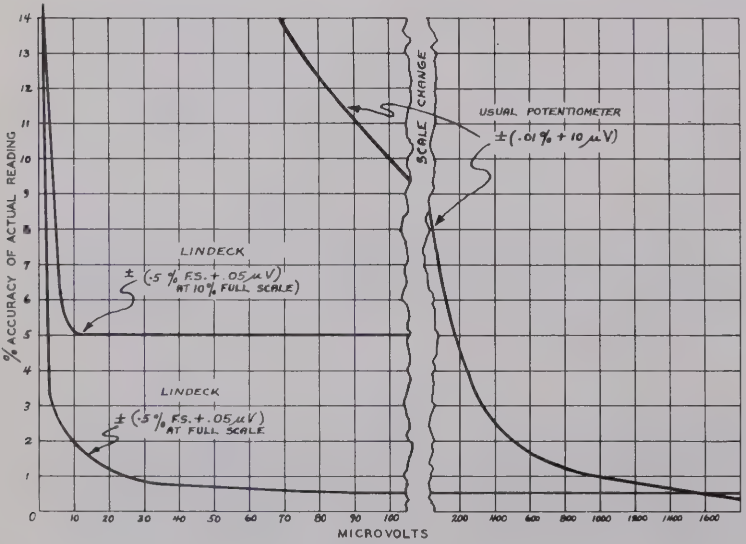


Figure 2

The resistance values of R_1 are adjusted to be accurate within .1%. The instrument M is our well known model C with an accuracy of .25%. This combination of accuracies can reasonably be expected to give an overall .35 of 1% accuracy and the model LE is actually guaranteed at a very conservative .5 of 1% full scale value.

This accuracy specification of .5 of 1% is WELL WORTH A SECOND LOOK. A direct comparison of the accuracies of such a LINDECK microvolt source with an ordinary .01% accurate potentiometer becomes very enlightening. The usual type of .01% potentiometer will have combined zero and thermal errors in the order of 10 to 20 microvolts. For purposes of comparison let us be reasonably conservative and say that the accuracy statement is ± (.01% of reading + 10 microvolts). This is to be compared with the accuracy statement for the Sensitive Research LINDECK Microvolt Source which is ± (.5% of full scale + .05 microvolt). In figure 2 we have shown comparative plots of these two accuracies in the low microvolt region. Because the LINDECK microvolt source varies in accuracy depending upon the scale position at which the pointer is being read, we are shown two different accuracy curves — one for full scale values and the other for values down at 1/10 of full scale. This is very much lower than is ever required except on the most sensitive range. It is readily seen that even at this reduced accuracy level the LINDECK type instrument becomes markedly better than the average potentiometer for the measurement of very low microvolt values.

This inherent ability to achieve a very low value of extraneous thermal EMFs and zero error, stems from the fact that there are no variable contacts any place in the microvolt circuit. Figure 1 shows plainly that directly across the output terminals there is only a very low and fixed value of resistance in the form of R_1. There are no switch contacts or slide wires or any other possible variable source of EMFs. Any contact potentials or variables in switches S_1 or S_2 do not contribute to errors in the output. They appear as merely variations in the battery B, and any variation stemming from this source will be included in the basic reading of instrument M.

The main advantage of the LINDECK type element is, of course, in the relative low microvolt ranges. However, as a matter of convenience, many higher ranges have been included in our model LE. This avoids the inconvenience of having to change equipment to a conventional type potentiometer when higher ranges are required at lesser accuracies. An additional convenient feature provided in the Sensitive Research version of the LINDECK microvolt source, is a very convenient means of self-checking the accuracy of the circuit.

A pair of external binding posts and an additional 5 ampere range on the instrument M provide a ready means of checking the calibration of resistors R_1. The resistors, which comprise R_1 are of very low value and are made to handle currents of at least 5 amperes without appreciable change in their characteristics. At this increased current the output voltages of the model LE are increased by a factor of 5000 to 1 over the normal X1 position.

At this level the output can readily be checked by an ordinary potentiometer to insure a satisfactory degree of over-all accuracy. This check is readily accomplished by providing an external source of adjustable 5 ampere current. An ordinary potentiometer is connected across the output terminals of the LINDECK and actual output values read. For full scale of the instrument M these values should be exactly 5000 times the engraved switch positions.

GENERAL OPERATION

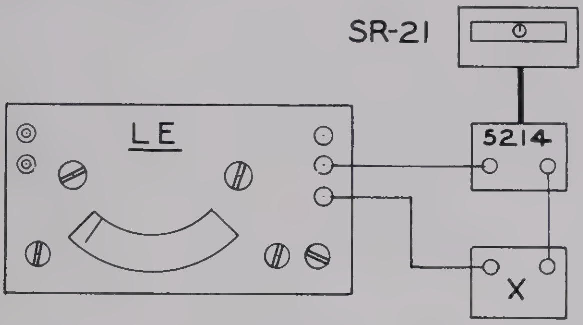
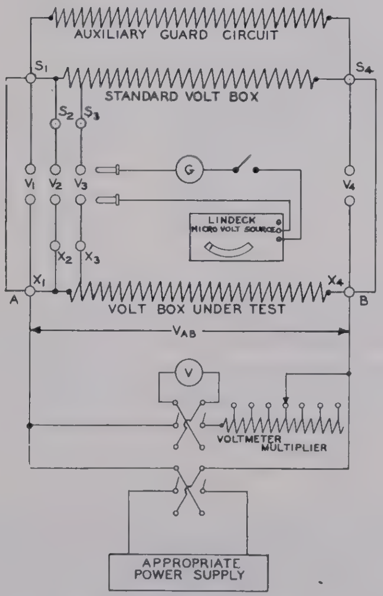


Figure 3

Figure 3 shows the general connection for the use of the model LE for the measurement of a source of microvolt potentials shown as the block box marked X. The diagram shows the instrument connected with a model 5214 Commander galvanometer amplifier and the output of the amplifier fed to a Commander SR 21 galvanometer (See our general catalog). The operation of the model LE is to cause it to produce an equal and opposite microvolt source in order to bring the SR 21 galvanometer to zero. This is done by selecting an appropriate range of voltage by means of the range selector and the X1, X10 range switch. The coarse and fine potential adjustment knobs are adjusted until the SR 21 indicates zero deflection. When this null is obtained, the value of microvolts appearing at the terminals of the LINDECK is determined by reading the scale of the instrument, the range selector and the X1, X10 range switch. These controls will give the value of the voltage appearing and the normal-reverse switch will show the polarity of this voltage, the normal position giving a polarity at the binding posts as indicated by the panel engraving.



VOLT BOX COMPARISON CIRCUIT

Figure 4

USE OF THE MODEL LE FOR INTERCOMPARISON OF VOLT BOXES

The LINDECK microvolt source provides one of the simplest and easiest methods for certifying a volt box against another standard volt box. The two boxes are connected in parallel across the power supply as shown in figure 4. An auxiliary guard circuit is shown on the standard volt box. This guard circuit is normally supplied in the highest accuracy type of volt boxes such as the Commander 9700 and 9700A. However, it is not required for this method of intercomparison except with such high accuracy instruments.

The voltage AB is adjusted by means of the power supply and the voltmeter V to the nominal value at which it is desired to intercompare the volt boxes. The 2 volt range of the model LE can be used with the normal output connection of the standard volt box to set the test voltage to approximate value. This eliminates the need for voltmeter V for setting the power supply voltage. The power supply does not have to be held accurately to this voltage, but merely to a stable value during the period of test. The voltages V_1, V_2, V_3 and V_4 are measured by the LINDECK microvolt source by adjusting it in each position to indicate zero on the galvanometer G. This galvanometer must have sufficient sensitivity to detect voltages of 1 or 2 microvolts. The Commander 5214 with its associated SR 21 galvanometer is recommended. However, with slightly less accuracy the model SR 4 Commander galvanometer can be substituted.

The correct ratio of the volt box under test will then be

$$R = R_S\,(1 + [(V_4 - V_1)/V_{AB}] - R_S\,[(V_3 - V_2)/V_{AB}]).$$

The above neglects second order and higher terms in the equation. The readings of the four values V_1, V_2, V_3 and V_4 are taken for all of the volt ratios at which the boxes are to be intercompared and corrections made for any known error with the standard volt box. The voltages V_1, V_2 and V_4 will usually be very small values compared to V_3 as they depend only on the resistance of connecting leads. The taking of these lead values can be ignored when measurements of lower accuracy are satisfactory. In this case the formula simplifies to $R_X = R_S\,(1 - F_S\,[V_S/V_{AB}])$.

INTERCOMPARISON OF STANDARD CELLS

The model LE microvolt source provides an excellent means of intercomparing standard cells to a very high degree of accuracy. The two standard cells to be compared are connected as shown in figure 5.

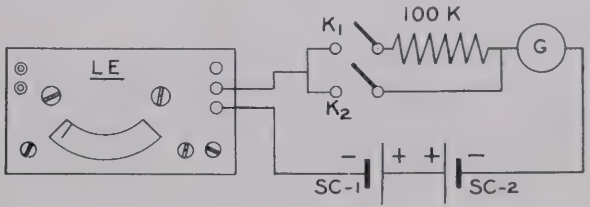


Figure 5

Once again the galvanometer G must be sufficiently sensitive to be able to detect fractional microvolt differences between the cells. The output of the LINDECK element is adjusted until zero galvanometer deflection is obtained when the keys are depressed.

In this standard cell measurement it is extremely important that the balance always be first obtained by means of the key 1, and that key 2 is not depressed until first a balance is obtained with key 1. In the event that there is a complete open or short circuit on either the unkown or the standard cell, this procedure will prevent damage to the standard. The reading of the LINDECK microvolt source will of course represent the difference between the value of SC 1, the standard, and SC 2, the cell under test. Addition or subtraction from the known value of the standard will be required to obtain the actual value of the unknown standard cell. Our Commander galvanometer amplifier model 5214 and the SR 21 are once again the recommended units for use as galvanometer G in figure 5; the SR 4 galvanometer can be substituted at a reduced accuracy.

GENERAL PRECAUTIONS REQUIRED

Measurement operations in the very low microvolt range require many careful techniques not ordinarily encountered. The avoidance of undesired thermal voltages comparable in magnitude to those being measured is very difficult in the low microvolt range where the LINDECK element is most used. For utmost accuracy it is almost an absolute requirement that measurements be made in a TEMPERATURE CONTROLLED AREA.

Further, all the instruments being measured should be allowed to stabilize at the temperature for a period of MANY HOURS before measurements are attempted. All connections between elements must be made with BARE (NOT TINNED) THINLY INSULATED COPPER WIRE. A good portion of the leads should be carefully wrapped around the copper binding post to insure good thermal contact. The galvanometer keys should be of a very low thermal type as ordinary types of galvanometer keys would themselves introduce thermals sufficiently large to give gross errors.

The Commander number 9145 low thermal switch is recommended for this application. Protective resistors in circuits such as the 100K shown in figure 5 should be of a stable wire wound type even though the accuracy does not enter into the overall measurement. Some types of composition resistors used in these applications provide relatively large extraneous voltages which are difficult to compensate or calculate.

The LINDECK microvolt source is many times used to determine residual thermals in apparatus that are of very low magnitude. Ordinarily this is accomplished with the circuit shown in figure 3. In this case the model LE combined with a 5214 galvanometer amplifier and the SR 21 galvanometer are being used to measure thermals in the block box X. All connections have been made with bare (un-tinned) thinly insulated copper wire, all of the gear has been in an air conditioned temperature controlled room for a period of many hours to reach overall stability.

If now the controls of the model LE are adjusted for balance on the SR 21 galvanometer a reading of voltage will be obtained. This reading will be the desired voltage originating in equipment X. It will also, however, include extraneous voltages from the wiring, from the 5214 and from the model LE itself.

After this first reading is taken, all connections should be left as shown in the diagram, and in addition a direct short placed across the equipment X. This short can best be in the form of a copper bar directly across the terminals involved. A second reading should be taken after this direct short is placed in position. As a matter of fact, the reading should be taken several minutes after the bar is in place because of possible thermal effects from your hand in connecting the bar.

This second reading will be that of all the extraneous EMF's other than the desired voltages originating in equipment X. This reading should be subtracted from the first reading. For utmost accuracy both readings should be taken several times to eliminate any possibility of slow drifts in any of the minute voltages invovled.

The average of such a group of readings will very closely approximate the actual value. Under these conditions readings to as low as .01 microvolt can be accomplished with a fair degree of reliability if extreme care is used.

If the user is not very familiar with the difficulties in taking measurements in the low microvolt region, it is suggested that set-ups similar to those shown in figure 3 be made and the effects of touching one of the terminals, of slight air currents, the use of tinned copper vs. bare copper wire and similar sources of difficulty be examined.

This will be an extremely enlightening experience for one not familiar with operations in this area of voltage. If due account is taken of all the error possibilities in this type of measurement excellent accuracies are obtainable. Without these rather slow painstaking techniques, measurements are of very little value.

LINDECK MICROVOLT SOURCE

ACCURACY
± (.5% of full scale + .05μv.)

READOUT INSTRUMENT
Accuracy .25%
Scale Length 6.3"
100 Divisions
Diamond Pivoted

RESOLUTION
.01μv./Division on 1μv. Range
Instrument can be interpolated to
tenths of 1 division or .001μv.

CODE
LINDECK

SELF CHECKING
Requires only a 5 ampere source
and an external potentiometer.

CASE
Formica 15⅞" x 10⅜" x 8"

APPROX. WEIGHT
21 lbs — Shipping 43 lbs.

RANGES
0 - 1/2/5/10/20/50/100/200/500 microvolts
& 1/2/5/200 millivolts & 2 volts

PRICE
$565.00

◆

For over 29 years we have published this company bulletin "ELECTRICAL MEASUREMENTS." In it we describe new instruments and measurement techniques. It is sent without cost to interested persons. If you have not been receiving this publication, please advise SENSITIVE RESEARCH."

Printed in U.S.A.

Prices and specifications subject
to change without notice.

Electrical MEASUREMENTS

VOLUME 29 APRIL, 1962 NUMBER 4

THE NEW LINDECK MICROVOLT SOURCE

ACCURACY ± (.5 of 1% of full scale + .05μv.)

LINDECK
MICROVOLT SOURCE
MODEL LE
SENSITIVE RESEARCH INSTRUMENT CORP.
NEW ROCHELLE NEW YORK USA
MICROVOLTS

MODEL **LE**

DIAMOND PIVOTED!

RESOLUTION .01μv. per division on the 1μv. range can be interpolated if required to .001μv.

The LINDECK element, as a source of highly accurate, very low microvolt potentials, has been in use since about 1899. A potentiometer, utilizing this principle, was first described by Lindeck and Rothe in that year. It was designed at that time primarily for the measurement of thermocouple EMF's.

It made use of a four terminal manganin resistance. The drop across this resistance was opposed to the unknown EMF in series with a galvanometer. The current through the resistor was adjustable by means of a separate rheostat and its value was read at balance by means of a milliammeter.

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

Symbol of Quality

The basic circuit of the LINDECK element in the Sensitive Research microvolt source is shown in figure 1.

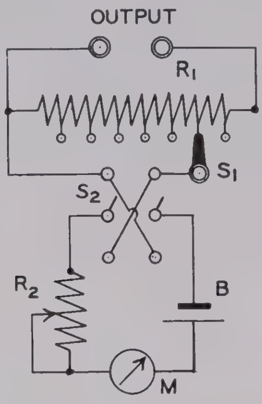


Figure 1

R_1 in this circuit, is a highly accurate and stable resistance. Switch S_1 provides a means for introducing a current into appropriate portions of R_1. The current is fed into the desired portion of R_1 from the battery B. The rheostat R_2, the polarity reversing switch S_2 and the milliammeter M provide means for adjusting and measuring the current in use.

Knowing the value of R_1 and the current indicated by the meter M, the exact microvolt output provided by this combination can be readily determined. In the Sensitive Research model LE microvolt source, these values for R_1 and M have been chosen so that the full scale reading of the milliammeter will provide microvolt values at the output from a low of 1 microvolt to a high of 5000 microvolts. This wide range is divided into a series of steps as follows: 0 - 1/2/5/100/200/500 microvolts.

These ranges are obtained by switching appropriate values of resistance by means of switch S_1. In addition the sensitivity of meter M is changed from a base range of 1 millampere to a range of 10 milliamperes by means of a panel switch marked X1 and X10.

The ten milliampere range multiplies the main range switch by a factor of ten to give a complete coverage on a 1, 2 and 5 basis from 1 microvolt to 5000 microvolts. A separate binding post gives a still higher output of .2 volt with the instrument measuring 1 milliampere and 2 volts with the milliammeter M in the X10 position.

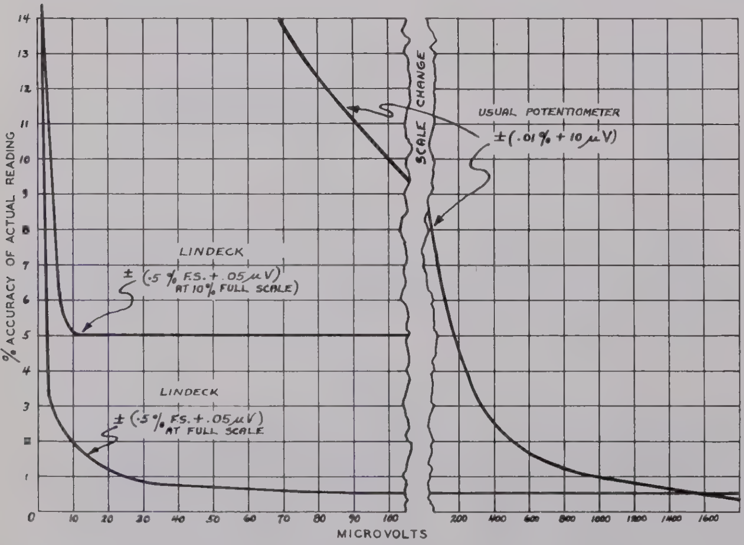


Figure 2

The resistance values of R_1 are adjusted to be accurate within .1%. The instrument M is our well known model C with an accuracy of .25%. This combination of accuracies can reasonably be expected to give an overall .35 of 1% accuracy and the model LE is actually guaranteed at a very conservative .5 of 1% full scale value.

This accuracy specification of .5 of 1% is WELL WORTH A SECOND LOOK. A direct comparison of the accuracies of such a LINDECK microvolt source with an ordinary .01% accurate potentiometer becomes very enlightening. The usual type of .01% potentiometer will have combined zero and thermal errors in the order of 10 to 20 microvolts. For purposes of comparison let us be reasonably conservative and say that the accuracy statement is ± (.01% of reading + 10 microvolts). This is to be compared with the accuracy statement for the Sensitive Research LINDECK Microvolt Source which is ± (.5% of full scale + .05 microvolt). In figure 2 we have shown comparative plots of these two accuracies in the low microvolt region. Because the LINDECK microvolt source varies in accuracy depending upon the scale position at which the pointer is being read, we are shown two different accuracy curves — one for full scale values and the other for values down at 1/10 of full scale. This is very much lower than is ever required except on the most sensitive range. It is readily seen that even at this reduced accuracy level the LINDECK type instrument becomes markedly better than the average potentiometer for the measurement of very low microvolt values.

This inherent ability to achieve a very low value of extraneous thermal EMFs and zero error, stems from the fact that there are no variable contacts any place in the microvolt circuit. Figure 1 shows plainly that directly across the output terminals there is only a very low and fixed value of resistance in the form of R_1. There are no switch contacts or slide wires or any other possible variable source of EMFs. Any contact potentials or variables in switches S_1 or S_2 do not contribute to errors in the output. They appear as merely variations in the battery B, and any variation stemming from this source will be included in the basic reading of instrument M.

The main advantage of the LINDECK type element is, of course, in the relative low microvolt ranges. However, as a matter of convenience, many higher ranges have been included in our model LE. This avoids the inconvenience of having to change equipment to a conventional type potentiometer when higher ranges are required at lesser accuracies. An additional convenient feature provided in the Sensitive Research version of the LINDECK microvolt source, is a very convenient means of self-checking the accuracy of the circuit.

A pair of external binding posts and an additional 5 ampere range on the instrument M provide a ready means of checking the calibration of resistors R_1. The resistors, which comprise R_1 are of very low value and are made to handle currents of at least 5 amperes without appreciable change in their characteristics. At this increased current the output voltages of the model LE are increased by a factor of 5000 to 1 over the normal X1 position.

At this level the output can readily be checked by an ordinary potentiometer to insure a satisfactory degree of over-all accuracy. This check is readily accomplished by providing an external source of adjustable 5 ampere current. An ordinary potentiometer is connected across the output terminals of the LINDECK and actual output values read. For full scale of the instrument M these values should be exactly 5000 times the engraved switch positions.

GENERAL OPERATION

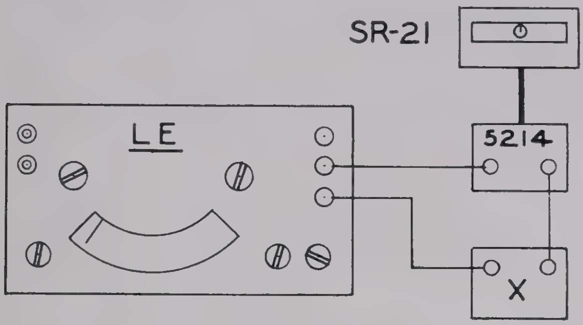
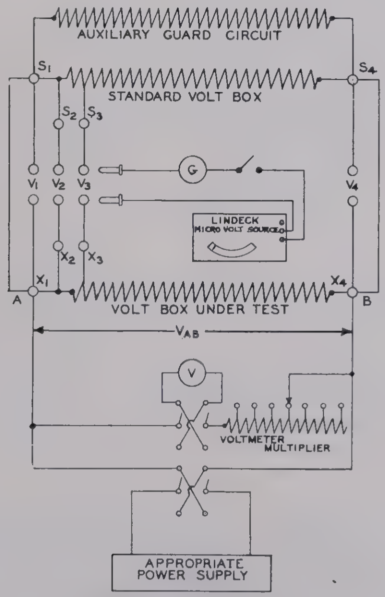


Figure 3

Figure 3 shows the general connection for the use of the model LE for the measurement of a source of microvolt potentials shown as the block box marked X. The diagram shows the instrument connected with a model 5214 Commander galvanometer amplifier and the output of the amplifier fed to a Commander SR 21 galvanometer (See our general catalog). The operation of the model LE is to cause it to produce an equal and opposite microvolt source in order to bring the SR 21 galvanometer to zero. This is done by selecting an appropriate range of voltage by means of the range selector and the X1, X10 range switch. The coarse and fine potential adjustment knobs are adjusted until the SR 21 indicates zero deflection. When this null is obtained, the value of microvolts appearing at the terminals of the LINDECK is determined by reading the scale of the instrument, the range selector and the X1, X10 range switch. These controls will give the value of the voltage appearing and the normal-reverse switch will show the polarity of this voltage, the normal position giving a polarity at the binding posts as indicated by the panel engraving.



VOLT BOX COMPARISON CIRCUIT

Figure 4

USE OF THE MODEL LE FOR INTERCOMPARISON OF VOLT BOXES

The LINDECK microvolt source provides one of the simplest and easiest methods for certifying a volt box against another standard volt box. The two boxes are connected in parallel across the power supply as shown in figure 4. An auxiliary guard circuit is shown on the standard volt box. This guard circuit is normally supplied in the highest accuracy type of volt boxes such as the Commander 9700 and 9700A. However, it is not required for this method of intercomparison except with such high accuracy instruments.

The voltage AB is adjusted by means of the power supply and the voltmeter V to the nominal value at which it is desired to intercompare the volt boxes. The 2 volt range of the model LE can be used with the normal output connection of the standard volt box to set the test voltage to approximate value. This eliminates the need for voltmeter V for setting the power supply voltage. The power supply does not have to be held accurately to this voltage, but merely to a stable value during the period of test. The voltages V_1, V_2, V_3 and V_4 are measured by the LINDECK microvolt source by adjusting it in each position to indicate zero on the galvanometer G. This galvanometer must have sufficient sensitivity to detect voltages of 1 or 2 microvolts. The Commander 5214 with its associated SR 21 galvanometer is recommended. However, with slightly less accuracy the model SR 4 Commander galvanometer can be substituted.

The correct ratio of the volt box under test will then be

$$R = R_S (1 + [(V_4 - V_1)/V_{AB}] - R_S [(V_3 - V_2)/V_{AB}]).$$

The above neglects second order and higher terms in the equation. The readings of the four values V_1, V_2, V_3 and V_4 are taken for all of the volt ratios at which the boxes are to be intercompared and corrections made for any known error with the standard volt box. The voltages V_1, V_2 and V_4 will usually be very small values compared to V_3 as they depend only on the resistance of connecting leads. The taking of these lead values can be ignored when measurements of lower accuracy are satisfactory. In this case the formula simplifies to $R_X = R_S (1 - F_S [V_S/V_{AB}])$.

INTERCOMPARISON OF STANDARD CELLS

The model LE microvolt source provides an excellent means of intercomparing standard cells to a very high degree of accuracy. The two standard cells to be compared are connected as shown in figure 5.

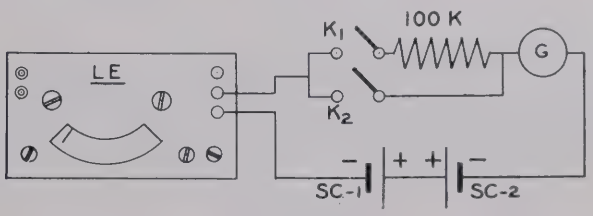


Figure 5

Once again the galvanometer G must be sufficiently sensitive to be able to detect fractional microvolt differences between the cells. The output of the LINDECK element is adjusted until zero galvanometer deflection is obtained when the keys are depressed.

In this standard cell measurement it is extremely important that the balance always be first obtained by means of the key 1, and that key 2 is not depressed until first a balance is obtained with key 1. In the event that there is a complete open or short circuit on either the unkown or the standard cell, this procedure will prevent damage to the standard. The reading of the LINDECK microvolt source will of course represent the difference between the value of SC 1, the standard, and SC 2, the cell under test. Addition or subtraction from the known value of the standard will be required to obtain the actual value of the unknown standard cell. Our Commander galvanometer amplifier model 5214 and the SR 21 are once again the recommended units for use as galvanometer G in figure 5; the SR 4 galvanometer can be substituted at a reduced accuracy.

GENERAL PRECAUTIONS REQUIRED

Measurement operations in the very low microvolt range require many careful techniques not ordinarily encountered. The avoidance of undesired thermal voltages comparable in magnitude to those being measured is very difficult in the low microvolt range where the LINDECK element is most used. For utmost accuracy it is almost an absolute requirement that measurements be made in a TEMPERATURE CONTROLLED AREA.

Further, all the instruments being measured should be allowed to stabilize at the temperature for a period of MANY HOURS before measurements are attempted. All connections between elements must be made with BARE (NOT TINNED) THINLY INSULATED COPPER WIRE. A good portion of the leads should be carefully wrapped around the copper binding post to insure good thermal contact. The galvanometer keys should be of a very low thermal type as ordinary types of galvanometer keys would themselves introduce thermals sufficiently large to give gross errors.

The Commander number 9145 low thermal switch is recommended for this application. Protective resistors in circuits such as the 100K shown in figure 5 should be of a stable wire wound type even though the accuracy does not enter into the overall measurement. Some types of composition resistors used in these applications provide relatively large extraneous voltages which are difficult to compensate or calculate.

The LINDECK microvolt source is many times used to determine residual thermals in apparatus that are of very low magnitude. Ordinarily this is accomplished with the circuit shown in figure 3. In this case the model LE combined with a 5214 galvanometer amplifier and the SR 21 galvanometer are being used to measure thermals in the block box X. All connections have been made with bare (un-tinned) thinly insulated copper wire, all of the gear has been in an air conditioned temperature controlled room for a period of many hours to reach overall stability.

If now the controls of the model LE are adjusted for balance on the SR 21 galvanometer a reading of voltage will be obtained. This reading will be the desired voltage originating in equipment X. It will also, however, include extraneous voltages from the wiring, from the 5214 and from the model LE itself.

After this first reading is taken, all connections should be left as shown in the diagram, and in addition a direct short placed across the equipment X. This short can best be in the form of a copper bar directly across the terminals involved. A second reading should be taken after this direct short is placed in position. As a matter of fact, the reading should be taken several minutes after the bar is in place because of possible thermal effects from your hand in connecting the bar.

This second reading will be that of all the extraneous EMF's other than the desired voltages originating in equipment X. This reading should be subtracted from the first reading. For utmost accuracy both readings should be taken several times to eliminate any possibility of slow drifts in any of the minute voltages invovled.

The average of such a group of readings will very closely approximate the actual value. Under these conditions readings to as low as .01 microvolt can be accomplished with a fair degree of reliability if extreme care is used.

If the user is not very familiar with the difficulties in taking measurements in the low microvolt region, it is suggested that set-ups similar to those shown in figure 3 be made and the effects of touching one of the terminals, of slight air currents, the use of tinned copper vs. bare copper wire and similar sources of difficulty be examined.

This will be an extremely enlightening experience for one not familiar with operations in this area of voltage. If due account is taken of all the error possibilities in this type of measurement excellent accuracies are obtainable. Without these rather slow painstaking techniques, measurements are of very little value.

LINDECK MICROVOLT SOURCE

ACCURACY
± (.5% of full scale + .05μv.)

READOUT INSTRUMENT
Accuracy .25%
Scale Length 6.3"
100 Divisions
Diamond Pivoted

RESOLUTION
.01μv./Division on 1μv. Range
Instrument can be interpolated to
tenths of 1 division or .001μv.

CODE
LINDECK

SELF CHECKING
Requires only a 5 ampere source
and an external potentiometer.

CASE
Formica 15⅞" x 10⅜" x 8"

APPROX. WEIGHT
21 lbs — Shipping 43 lbs.

RANGES
0 - 1/2/5/10/20/50/100/200/500 microvolts
& 1/2/5/200 millivolts & 2 volts

PRICE
$565.00

For over 29 years we have published this company bulletin "ELECTRICAL MEASUREMENTS." In it we describe new instruments and measurement techniques. It is sent without cost to interested persons. If you have not been receiving this publication, please advise SENSITIVE RESEARCH."

Printed in U.S.A.

Prices and specifications subject
to change without notice.

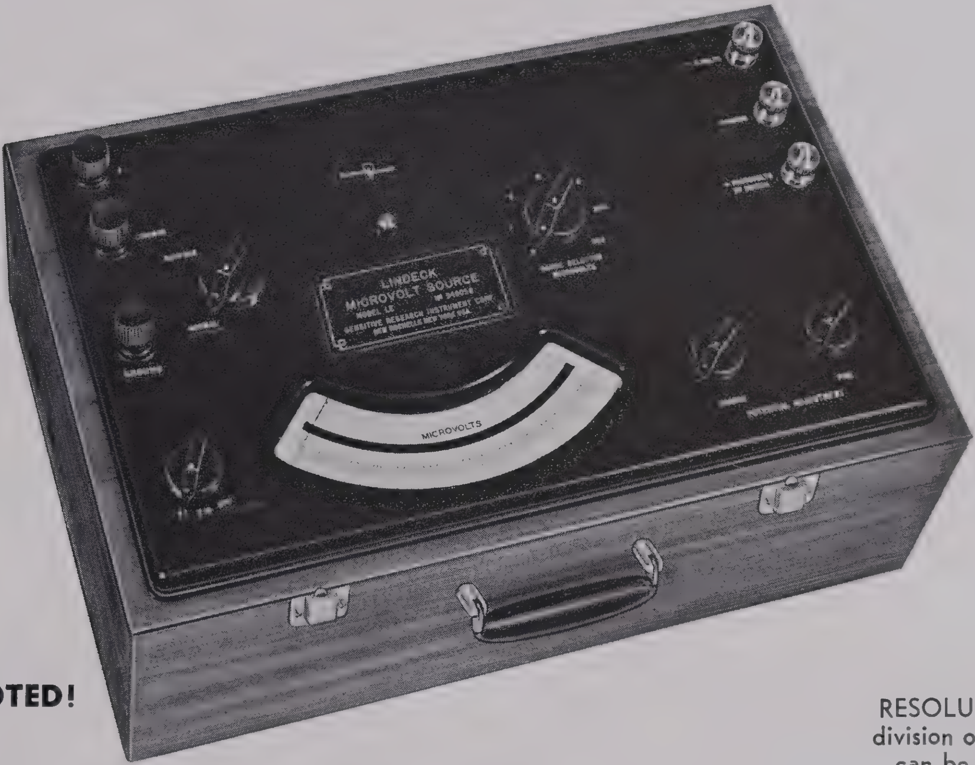
Electrical MEASUREMENTS

VOLUME 29 APRIL, 1962 NUMBER 4

THE NEW LINDECK MICROVOLT SOURCE

ACCURACY ± (.5 of 1% of full scale + .05μv.)

MODEL **LE**


LINDECK
MICROVOLT SOURCE
MODEL LE
SENSITIVE RESEARCH INSTRUMENT CORP.
NEW ROCHELLE NEW YORK U.S.A.
MICROVOLTS

DIAMOND PIVOTED!

RESOLUTION .01μv. per division on the 1μv. range can be interpolated if required to .001μv.

The LINDECK element, as a source of highly accurate, very low microvolt potentials, has been in use since about 1899. A potentiometer, utilizing this principle, was first described by Lindeck and Rothe in that year. It was designed at that time primarily for the measurement of thermocouple EMF's.

It made use of a four terminal manganin resistance. The drop across this resistance was opposed to the unknown EMF in series with a galvanometer. The current through the resistor was adjustable by means of a separate rheostat and its value was read at balance by means of a milliammeter.

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

Symbol of Quality

The basic circuit of the LINDECK element in the Sensitive Research microvolt source is shown in figure 1.

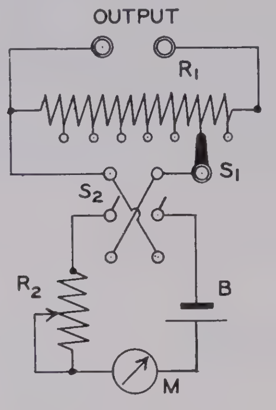


Figure 1

R_1 in this circuit, is a highly accurate and stable resistance. Switch S_1 provides a means for introducing a current into appropriate portions of R_1. The current is fed into the desired portion of R_1 from the battery B. The rheostat R_2, the polarity reversing switch S_2 and the milliammeter M provide means for adjusting and measuring the current in use.

Knowing the value of R_1 and the current indicated by the meter M, the exact microvolt output provided by this combination can be readily determined. In the Sensitive Research model LE microvolt source, these values for R_1 and M have been chosen so that the full scale reading of the milliammeter will provide microvolt values at the output from a low of 1 microvolt to a high of 5000 microvolts. This wide range is divided into a series of steps as follows: 0 - 1/2/5/100/200/500 microvolts.

. . These ranges are obtained by switching appropriate values of resistance by means of switch S_1. In addition the sensitivity of meter M is changed from a base range of 1 millampere to a range of 10 milliamperes by means of a panel switch marked X1 and X10.

The ten milliampere range multiplies the main range switch by a factor of ten to give a complete coverage on a 1, 2 and 5 basis from 1 microvolt to 5000 microvolts. A separate binding post gives a still higher output of .2 volt with the instrument measuring 1 milliampere and 2 volts with the milliammeter M in the X10 position.

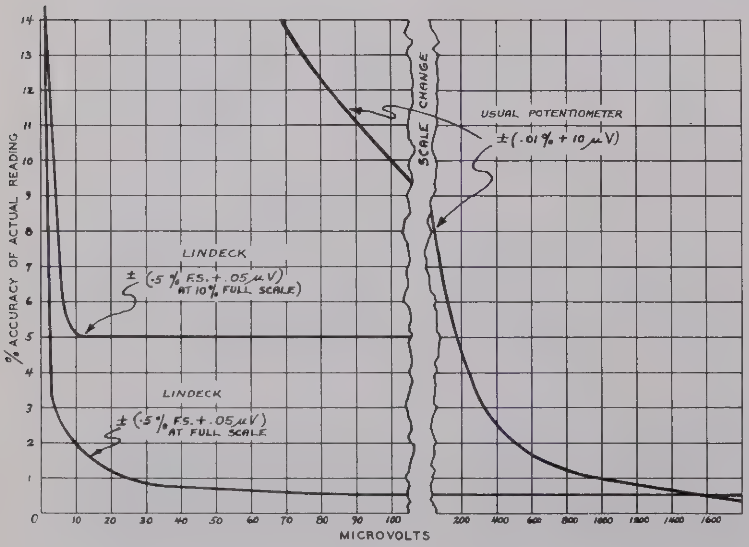


Figure 2

The resistance values of R_1 are adjusted to be accurate within .1%. The instrument M is our well known model C with an accuracy of .25%. This combination of accuracies can reasonably be expected to give an overall .35 of 1% accuracy and the model LE is actually guaranteed at a very conservative .5 of 1% full scale value.

This accuracy specification of .5 of 1% is WELL WORTH A SECOND LOOK. A direct comparison of the accuracies of such a LINDECK microvolt source with an ordinary .01% accurate potentiometer becomes very enlightening. The usual type of .01% potentiometer will have combined zero and thermal errors in the order of 10 to 20 microvolts. For purposes of comparison let us be reasonably conservative and say that the accuracy statement is ± (.01% of reading + 10 microvolts). This is to be compared with the accuracy statement for the Sensitive Research LINDECK Microvolt Source which is ± (.5% of full scale + .05 microvolt). In figure 2 we have shown comparative plots of these two accuracies in the low microvolt region. Because the LINDECK microvolt source varies in accuracy depending upon the scale position at which the pointer is being read, we are shown two different accuracy curves — one for full scale values and the other for values down at 1/10 of full scale. This is very much lower than is ever required except on the most sensitive range. It is readily seen that even at this reduced accuracy level the LINDECK type instrument becomes markedly better than the average potentiometer for the measurement of very low microvolt values.

This inherent ability to achieve a very low value of extraneous thermal EMFs and zero error, stems from the fact that there are no variable contacts any place in the microvolt circuit. Figure 1 shows plainly that directly across the output terminals there is only a very low and fixed value of resistance in the form of R_1. There are no switch contacts or slide wires or any other possible variable source of EMFs. Any contact potentials or variables in switches S_1 or S_2 do not contribute to errors in the output. They appear as merely variations in the battery B, and any variation stemming from this source will be included in the basic reading of instrument M.

The main advantage of the LINDECK type element is, of course, in the relative low microvolt ranges. However, as a matter of convenience, many higher ranges have been included in our model LE. This avoids the inconvenience of having to change equipment to a conventional type potentiometer when higher ranges are required at lesser accuracies. An additional convenient feature provided in the Sensitive Research version of the LINDECK microvolt source, is a very convenient means of self-checking the accuracy of the circuit.

A pair of external binding posts and an additional 5 ampere range on the instrument M provide a ready means of checking the calibration of resistors R_1. The resistors, which comprise R_1 are of very low value and are made to handle currents of at least 5 amperes without appreciable change in their characteristics. At this increased current the output voltages of the model LE are increased by a factor of 5000 to 1 over the normal X1 position.

At this level the output can readily be checked by an ordinary potentiometer to insure a satisfactory degree of over-all accuracy. This check is readily accomplished by providing an external source of adjustable 5 ampere current. An ordinary potentiometer is connected across the output terminals of the LINDECK and actual output values read. For full scale of the instrument M these values should be exactly 5000 times the engraved switch positions.

GENERAL OPERATION

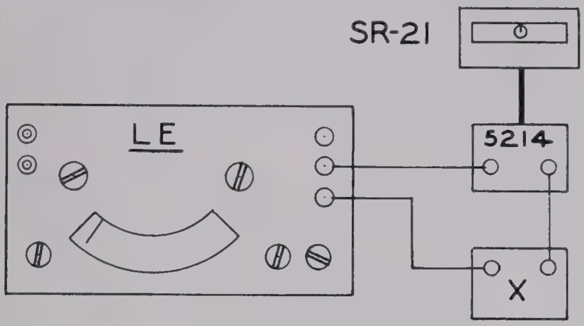
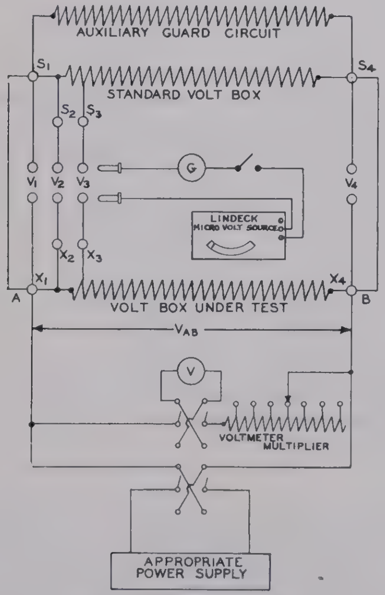


Figure 3

Figure 3 shows the general connection for the use of the model LE for the measurement of a source of microvolt potentials shown as the block box marked X. The diagram shows the instrument connected with a model 5214 Commander galvanometer amplifier and the output of the amplifier fed to a Commander SR 21 galvanometer (See our general catalog). The operation of the model LE is to cause it to produce an equal and opposite microvolt source in order to bring the SR 21 galvanometer to zero. This is done by selecting an appropriate range of voltage by means of the range selector and the X1, X10 range switch. The coarse and fine potential adjustment knobs are adjusted until the SR 21 indicates zero deflection. When this null is obtained, the value of microvolts appearing at the terminals of the LINDECK is determined by reading the scale of the instrument, the range selector and the X1, X10 range switch. These controls will give the value of the voltage appearing and the normal-reverse switch will show the polarity of this voltage, the normal position giving a polarity at the binding posts as indicated by the panel engraving.



VOLT BOX COMPARISON CIRCUIT

Figure 4

USE OF THE MODEL LE FOR INTERCOMPARISON OF VOLT BOXES

The LINDECK microvolt source provides one of the simplest and easiest methods for certifying a volt box against another standard volt box. The two boxes are connected in parallel across the power supply as shown in figure 4. An auxiliary guard circuit is shown on the standard volt box. This guard circuit is normally supplied in the highest accuracy type of volt boxes such as the Commander 9700 and 9700A. However, it is not required for this method of intercomparison except with such high accuracy instruments.

The voltage AB is adjusted by means of the power supply and the voltmeter V to the nominal value at which it is desired to intercompare the volt boxes. The 2 volt range of the model LE can be used with the normal output connection of the standard volt box to set the test voltage to approximate value. This eliminates the need for voltmeter V for setting the power supply voltage. The power supply does not have to be held accurately to this voltage, but merely to a stable value during the period of test. The voltages V_1, V_2, V_3 and V_4 are measured by the LINDECK microvolt source by adjusting it in each position to indicate zero on the galvanometer G. This galvanometer must have sufficient sensitivity to detect voltages of 1 or 2 microvolts. The Commander 5214 with its associated SR 21 galvanometer is recommended. However, with slightly less accuracy the model SR 4 Commander galvanometer can be substituted.

The correct ratio of the volt box under test will then be
$R = R_S\,(1 + [(V_4 - V_1)/V_{AB}] - R_S\,[(V_3 - V_2)/V_{AB}])$.
The above neglects second order and higher terms in the equation. The readings of the four values V_1, V_2, V_3 and V_4 are taken for all of the volt ratios at which the boxes are to be intercompared and corrections made for any known error with the standard volt box. The voltages V_1, V_2 and V_4 will usually be very small values compared to V_3 as they depend only on the resistance of connecting leads. The taking of these lead values can be ignored when measurements of lower accuracy are satisfactory. In this case the formula simplifies to $R_X = R_S\,(1 - F_S\,[\,V_S/V_{AB}])$.

INTERCOMPARISON OF STANDARD CELLS

The model LE microvolt source provides an excellent means of intercomparing standard cells to a very high degree of accuracy. The two standard cells to be compared are connected as shown in figure 5.

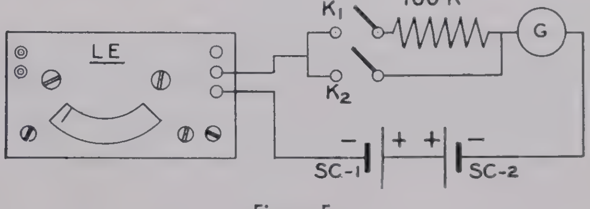


Figure 5

Once again the galvanometer G must be sufficiently sensitive to be able to detect fractional microvolt differences between the cells. The output of the LINDECK element is adjusted until zero galvanometer deflection is obtained when the keys are depressed.

In this standard cell measurement it is extremely important that the balance always be first obtained by means of the key 1, and that key 2 is not depressed until first a balance is obtained with key 1. In the event that there is a complete open or short circuit on either the unkown or the standard cell, this procedure will prevent damage to the standard. The reading of the LINDECK microvolt source will of course represent the difference between the value of SC 1, the standard, and SC 2, the cell under test. Addition or subtraction from the known value of the standard will be required to obtain the actual value of the unknown standard cell. Our Commander galvanometer amplifier model 5214 and the SR 21 are once again the recommended units for use as galvanometer G in figure 5; the SR 4 galvanometer can be substituted at a reduced accuracy.

GENERAL PRECAUTIONS REQUIRED

Measurement operations in the very low microvolt range require many careful techniques not ordinarily encountered. The avoidance of undesired thermal voltages comparable in magnitude to those being measured is very difficult in the low microvolt range where the LINDECK element is most used. For utmost accuracy it is almost an absolute requirement that measurements be made in a TEMPERATURE CONTROLLED AREA.

Further, all the instruments being measured should be allowed to stabilize at the temperature for a period of MANY HOURS before measurements are attempted. All connections between elements must be made with BARE (NOT TINNED) THINLY INSULATED COPPER WIRE. A good portion of the leads should be carefully wrapped around the copper binding post to insure good thermal contact. The galvanometer keys should be of a very low thermal type as ordinary types of galvanometer keys would themselves introduce thermals sufficiently large to give gross errors.

The Commander number 9145 low thermal switch is recommended for this application. Protective resistors in circuits such as the 100K shown in figure 5 should be of a stable wire wound type even though the accuracy does not enter into the overall measurement. Some types of composition resistors used in these applications provide relatively large extraneous voltages which are difficult to compensate or calculate.

The LINDECK microvolt source is many times used to determine residual thermals in apparatus that are of very low magnitude. Ordinarily this is accomplished with the circuit shown in figure 3. In this case the model LE combined with a 5214 galvanometer amplifier and the SR 21 galvanometer are being used to measure thermals in the block box X. All connections have been made with bare (un-tinned) thinly insulated copper wire, all of the gear has been in an air conditioned temperature controlled room for a period of many hours to reach overall stability.

If now the controls of the model LE are adjusted for balance on the SR 21 galvanometer a reading of voltage will be obtained. This reading will be the desired voltage originating in equipment X. It will also, however, include extraneous voltages from the wiring, from the 5214 and from the model LE itself.

After this first reading is taken, all connections should be left as shown in the diagram, and in addition a direct short placed across the equipment X. This short can best be in the form of a copper bar directly across the terminals involved. A second reading should be taken after this direct short is placed in position. As a matter of fact, the reading should be taken several minutes after the bar is in place because of possible thermal effects from your hand in connecting the bar.

This second reading will be that of all the extraneous EMF's other than the desired voltages originating in equipment X. This reading should be subtracted from the first reading. For utmost accuracy both readings should be taken several times to eliminate any possibility of slow drifts in any of the minute voltages invovled.

The average of such a group of readings will very closely approximate the actual value. Under these conditions readings to as low as .01 microvolt can be accomplished with a fair degree of reliability if extreme care is used.

If the user is not very familiar with the difficulties in taking measurements in the low microvolt region, it is suggested that set-ups similar to those shown in figure 3 be made and the effects of touching one of the terminals, of slight air currents, the use of tinned copper vs. bare copper wire and similar sources of difficulty be examined.

This will be an extremely enlightening experience for one not familiar with operations in this area of voltage. If due account is taken of all the error possibilities in this type of measurement excellent accuracies are obtainable. Without these rather slow painstaking techniques, measurements are of very little value.

LINDECK MICROVOLT SOURCE

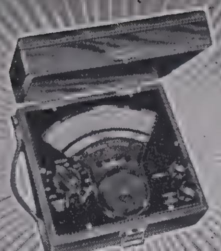
ACCURACY
± (.5% of full scale + .05μv.)
READOUT INSTRUMENT
Accuracy .25%
Scale Length 6.3"
100 Divisions
Diamond Pivoted
RESOLUTION
.01μv./Division on 1μv. Range
Instrument can be interpolated to
tenths of 1 division or .001μv.
CODE
LINDECK
SELF CHECKING
Requires only a 5 ampere source
and an external potentiometer.
CASE
Formica 15⅞" x 10⅜" x 8"
APPROX. WEIGHT
21 lbs — Shipping 43 lbs.
RANGES
0 - 1/2/5/10/20/50/100/200/500 microvolts
& 1/2/5/200 millivolts & 2 volts
PRICE
$565.00

◆

For over 29 years we have published this company bulletin "ELECTRICAL MEASUREMENTS." In it we describe new instruments and measurement techniques. It is sent without cost to interested persons. If you have not been receiving this publication, please advise SENSITIVE RESEARCH."

Printed in U.S.A.

Prices and specifications subject
to change without notice.

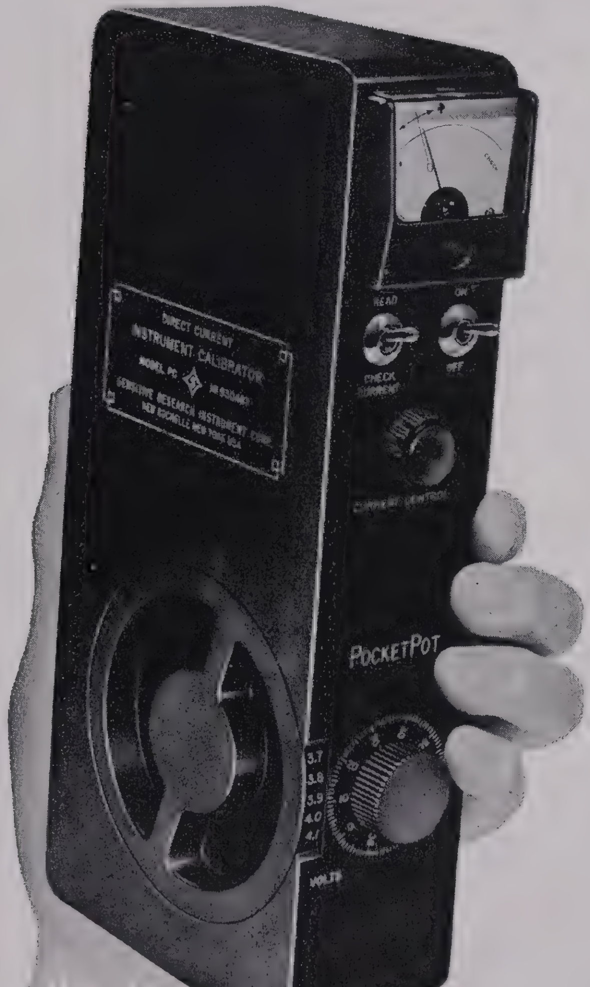


Electrical MEASUREMENTS

VOLUME 28 JULY, 1961 NUMBER 7

"POCKETPOT"

(A NEW MINIATURIZED POCKET SIZE POTENTIOMETER)


DIRECT CURRENT
INSTRUMENT CALIBRATOR
MODEL PC
SENSITIVE RESEARCH INSTRUMENT CORP.
NEW ROCHELLE NEW YORK U.S.A.
READ
ON
CHECK CURRENT
OFF
CURRENT CONTROL
PocketPot
3.7
3.8
3.9
4.0
4.1
VOLTS

ACCURACY

± .05% of reading or .5 millivolt, whichever is the greater.

RANGE

0 - 5.00 volts

SENSITIVITY

Infinite impedance

RESOLUTION

.5 millivolt

SIZE

9" x 4¼" x 1¾"

WEIGHT

3 pounds

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

S

Symbol of Quality

....TO MEASURE IS TO KNOW....

The Model PC POCKETPOT is a .05% accurate, miniaturized DC Potentiometer for use as an infinite impedance calibrator and measuring instrument. It is available with a "plug in" switch controlled Current-Volt-Box of the same size and shape which extends its basic range of 0 - 5.00 volt to 500 v and 0 - 1 amp. Overall accuracy of both units when used together is .1% of reading over the upper four-fifths of the ranges.

The uniqueness of the POCKETPOT is that in spite of its small size, it is a completely self-contained high accuracy potentiometer with internal galvanometer, standard reference source and direct "in line" dial readout. It is battery operated and therefore, unlike most electronic instrumentation designed for field measurements, it does not require an AC power source. Even when connected to the Model PC-S Current-Volt-Box, it may easily be held and operated in the *palm of the hand!*

The POCKETPOT pictured on page one is a marked innovation in measurement techniques for field use. No other instrument currently available combines in one small sized unit, the accuracy or the sensitivity of this instrument. With the accompanying range extension unit the POCKETPOT accomplishes most of the DC measurements required in general field servicing or calibration of test facilities.

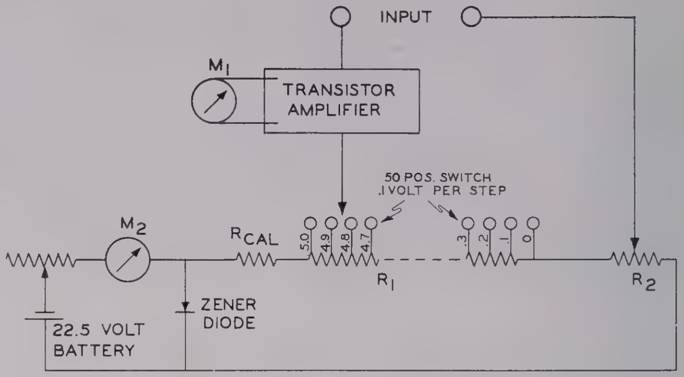
The two units in a cconvenient leather carrying case constitute practically a portable DC standards laboratory. The POCKETPOT by itself provides a convenient and hand held portable unit for measurements in the corrosion field and other low voltage applications. It is considerably more rugged than the high sensitivity types of voltmeters commonly used, and simpler in operation and smaller than potentiometer type voltmeters.

The POCKETPOT is a true potentiometer providing infinite impedance readings at balance. Its basic circuit is shown in Fig. 1. It contains several unique features.

As in all potentiometers, a current is standardized through a chain of resistors, R_1 and R_2, to provide a known voltage drop across them, which is compared by a high sensitivity detector to the external voltage.

Indication of zero on the "null" detector shows equality between the internal and external voltages and the resistor switch settings provide readings of the voltage directly from their position. In order to provide a high sensitivity null detector in a very small space, a tiny transistor amplifier has been used in this instrument to feed a small rugged indicator for the actual null indications. This detector gives a sensitivity well in excess of .1 millivolt, which is ample for the ranges involved.

In order to accurately standardize the current in the potentiometer, we use the extremely steep voltage-current characteristic of a zero temperature coefficient Zener diode. The same instrument used as the null detector is switched into position to measure the current supplied into the Zener diode network shown at M_2 in Figure 1.



BASIC CIRCUIT OF "POCKET POT"

Fig. 1

The current for the Zener diode is supplied by the 22.5 volt battery through a series rheostat so that the current may be adjusted to a specified value regardless of the age and condition of the battery.

This current read by the meter in position M_2 can be adjusted to a repeatable point within ± 1% satisfactorily.

Due to the extremely steep slope of the characteristic curve of the Zener diode used, adjustment of this current to within 1% allows the operating voltage of the Zener diode to be determined to better than .01%. This stabilized voltage is then used to supply the constant current through the potentiometer resistive network. Under these conditions a battery with a nominal 22.5 volt supply can be used until it has dropped to approximately 15 volts, and the actual voltage applied to the potentiometer portion of the circuit itself still held within .01%.

This circuit is responsible for the basic accuracy of the instrument. This circuit also eliminates completely the difficulties involved in using standard cells for standardizing purposes in the potentiometer. Standard cells would be troublesome due to transportation and temperature variations. The Zener diode used in this circuit is of the zero temperature coefficicent type and introduces a temperature coefficient of not more than .001% °C, allowing completely satisfactory operation over an extremely wide range of temperatures. In fact, the POCKETPOT will operate satisfactorily over a range of temperatures greater than the operator can comfortably withstand.

Operation of the POCKETPOT is extremely simple. All that is required is to energize the instrument by means of a small toggle switch and set the meter on the panel to the "check current" position. This standardizes the current into the Zener diode and the entire potentiometer network.

Then switch the meter to the "read" position which connects the indicator to the output of the transistor amplifier for use as a null detector. Then rotate the voltage dials until the meter reading as a null detector returns to zero.

The exact voltage is then read directly from the in-line dials. The reading is extremely simple and direct, not even requiring the operator to guess at the decimal point position as it is plainly marked.

The long term accuracy of the POCKETPOT is assured by three readily accessible adjustment screws on the back of the instrument. These are marked "Zero Adjust Short Circuit," "Zero Adjust Open Circuit," and "Calibration."

The "Zero Adjust Short Circuit" and the "Zero Adjust Open Circuit" provide for variations which might occur in the transistors with time, usage, temperature variations, and things of this general nature. They require only an occasional adjustment and as the name implies, one first adjusts the short circuit zero null indication by shorting the two output terminals and adjusting this control to indicate exactly zero when the potentiometer is turned to the zero position.

Having done this, one removes the short circuit from the input terminals and adjusts the zero open circuit for the same null indication. This assures that any long term variations in the transistors due to either their own aging or battery depreciation can be satisfactorily compensated.

To take care of any possible long term variation in either the Zener diode voltage or in the resistor chain variation itself, one need only apply a known accurate voltage to the input terminals . Adjust the dials to this known voltage at the input terminals.

If the zero indicator does not indicate zero, showing perfect calibration of the POCKETPOT, a slight readjustment of the calibration control will bring this to exact coincidence between the known stanlardizing voltage and the POCKETPOT.

The inherent long term stability of the POCKETPOT and its basic accuracy is so great that this calibration adjustment should NOT BE MADE unless you have a calibrating source with an accuracy of at least .01% known value. Re-adjustment of the POCKETPOT against a standard of any lesser accuracy would be a very doubtful procedure.

It is suggested that probably the simplest thing is to connect the POCKETPOT to a known good standard cell and set the dials for the known values of this cell in making this adjustment.

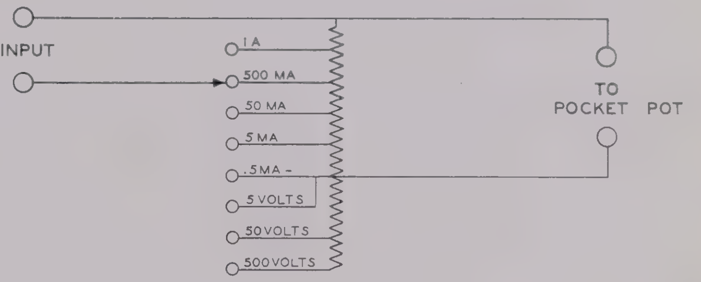
However, any voltage in the general range from 1 to 5 volts which is accurately known will be perfectly satisfactory for this adjustment. It is, however, undesirable to use a standard voltage appreciably below one volt, because under these conditions slight errors due to thermal voltages would become of appreciable accuracy importance.

These calibration precautions are themselves indicative of the basic accuracy of the potentiometer. Ordinarily these adjustments would be made very infrequently. Exactly how frequently will depend on the usage of the instrument, exposure to wide extremes of temperature, vibration, shock and things of this general nature.

It is suggested that the zero adjustment procedure should be checked at any time that the instrument is used under unusual conditions of extreme cold or heat. It probably will require attention under ideal operating conditions of possibly one every ten hours of operation due to possible battery depreciation.

The complete calibration adjustment against an external standard will also depend upon the type of usage to which the instrument is subjected. In no case should it be necessary to accomplish this more than once a month and in normal operation under reasonable conditions probably once in six months will be ample to maintain satisfactory calibration accuracy. This factor can only be determined by the user under his particular conditions of operation.

For full maximum accuracy the unit is intended to be operated in a horizontal position. However, position sensitivity of the indicating instrument will introduce only very slight errors and it can, for ordinary usage, be operated hand held with very slight deterioration of overall accuracy.



RANGE EXTENSION UNIT
FOR "POCKET POT"

Fig. 2

Figure 2 shows the circuit of the range extension unit for use with the POCKETPOT. This is a completely straight forward type of universal shunt and additional voltage resistors to provide ranges of voltages and current which are compatible with the scales of the instruments.

Current ranges are 0 - .05/5/50/500 milliamperes. There is also a 5 ampere range, however, due to wattage involved, the 5 ampere range can only be satisfactorily used up to 1 ampere, and hence, one ampere is marked on this switch position.

Momentary operation of not more than 30 seconds in any 5 minutes can however, be tolerated at a 5 ampere rating. The engraved one ampere is based on continuous operation within the rated accuracy of the instrument.

These ranges are all direct reading from the dial. The .5 milliampere range requiring only moving the decimal point one place to the left. In other words, when the dials indicates 1.000 the actual reading is .1 milliampere. Likewise, on the 5 milliampere position the readings would be read directly in milliamperes without any decimal point position change. For the

50 milliampere position the decimal point is moved one place to the right. In other words, the normal 1 volt position becomes a 10 milliampere position. On the 1 ampere position, the ranges are once again direct reading from zero to 1 ampere which would be the one volt normal position. For continuous usage it should not be used above this point, but of course the 2 volt position becomes a 2 ampere position, a 3 ampere position and so forth for momentary use only.

The volt positions likewise match exactly the scale involved. The 5 volt position actually reads direct from the dial, exactly the same as though the instrument was used by itself, except in this case a 2000 ohms per volt resistor is shunted across the input and it is no longer an infinite impedance device.

Additional series resistances are added to provide 50 volt and 500 volt positions. Obviously, when the 500 volt range is in use the decimal point must be mentally moved two places to the right. The normal 1 volt position equals 100 volts when used with the range extension unit on the 500 volt range.

This POCKETPOT instrument together with its range extension unit becomes so universal for DC measurement, that it is the type of device that one would expect people involved with quality control to carry for all types of routine instrument checks. In addition to its wide general purpose appeal it is ideally suited for corrosion measurements.

The ranges of electro chemical potentials usually encountered in corrosion protection work, are adequately covered by the basic zero to 5 volt range of the instrument and due to the inherent high accuracy it can be used down to its last division satisfactorily for this type of measurement.

It can in effect be said to cover a range from 1 millivolt to 5 volts for this type of operation. The basic accuracy will be surprisingly high, because of the infinite impedance feature of true potentiometric measurements. The main errors of most instruments used for corrosion measurements are not the basic inaccuracies of the instruments themselves, but the fact that even the highest resistance instrument actually does consume appreciable current.

The errors are inherent in the measurement because of this current flow which upsets the original operating conditions and gives an incorrect reading due to the voltage drop through the high resistances normally encountered in corrosion work. The potentiometric operation of the POCKETPOT completely eliminates this source of error, and hence, basic accuracies become markedly higher than with other types of instruments.

In addition, the instrument is small, very compact, self-contained and is markedly more rugged than any of the direct indicating type of instruments previously used. It is ideally suited for those people who must make measurements in the corrosion field where they are made in cramped manholes and similarly inconvenient places. Its use is particularly recommended for this type of operation.

The same instrument, of course, with the range extension unit added will cover the entire range of voltages involved in most of the cathodic type protection equipment with which this same group works and can be used for measurements of the output voltages of these devices, to eliminate the need of a second instrument for maintenance.

It will be obvious if you have read this far in this description of the instrument that we think rather highly of this little pocket gem. We will rather dislike to see it replace ALL of the big high accuracy test consoles there are in the country, but it can replace a surprisingly high number of them, and still be small enough to be your own personal instrument carried in your own coat pocket if desirable. We suggest that you join the "Standards Lab In My Pocket" brigade and enjoy complete high accuracy confidence in your field measurements.

SPECIFICATIONS

POCKETPOT
Model PC

ACCURACY:	± .05% of reading or .5 mv, whichever is the greater
RANGE:	10 mv - 5.00 v DC
SENSITIVITY:	Infinite impedance
CASE:	Molded black bakelite
SIZE:	9" x 4¼" x 1¾"
WEIGHT:	3 lbs.
SHIPPING WEIGHT:	8 lbs.
PRICE:	$325.00

Supplied with complete operating instructions. A leather carrying case is available at additional cost.

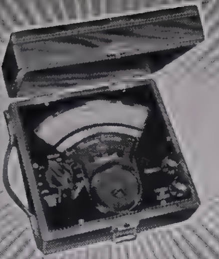
CURRENT - VOLT - BOX
Model PC-S

ACCURACY:	± .05%
RANGES:	.5/5/50/500 ma; 1 ampere 5/50/500 v 5 amperes momentarily
SENSITIVITY:	All current ranges 5 v drop, excepting 1 ampere range 1 v drop. All volt ranges 2000 Ω/v
PRICE:	$125.00

For over 27 years we have published this company bulletin "ELECTRICAL MEASUREMENTS." In it we decribe new instruments and measurement techniques. It is sent without cost to interested persons. If you have not been receiving this publication, please advise "SENSITIVE RESEARCH."

Printed in U.S.A.

Prices and specifications subject to change without notice.



Electrical MEASUREMENTS

VOLUME 28 JUNE, 1961 NUMBER 6

MODEL RFVC

RADIO FREQUENCY
VOLTAGE
CALIBRATOR

ACCURACY
.5% to 10 megacycles
except .010 v. range
which is 1%.

MODEL TPW

THREE PHASE
VOLT-AMP-
WATTMETER

ACCURACY
Watts — 1/2%
Volts — 1/4%
Amperes — 1/4%

For use at 50 - 500 cycles

SENSITIVE RESEARCH
INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

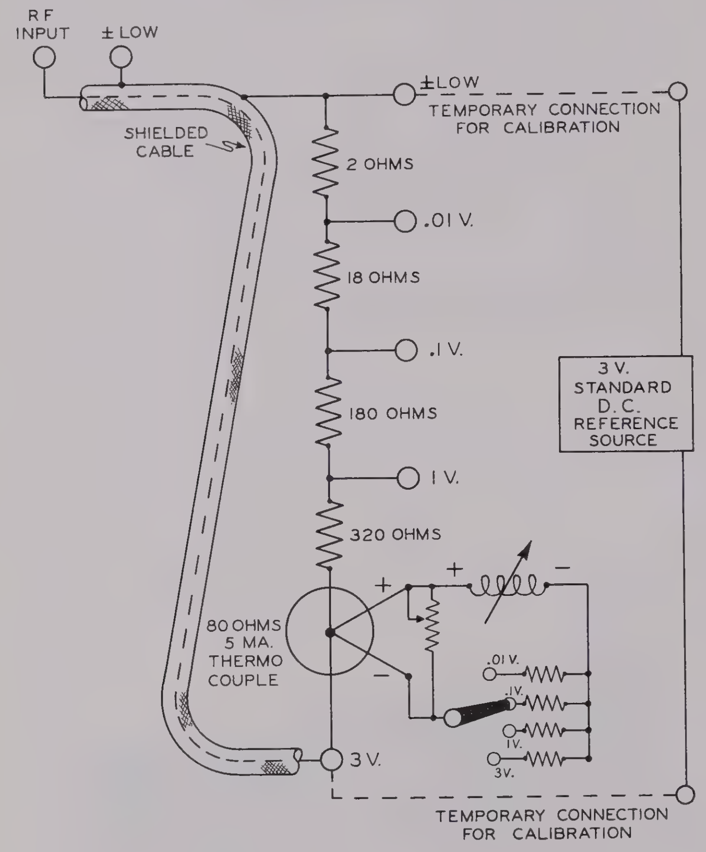
ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

S

Symbol of Quality

RADIO FREQUENCY VOLTAGE CALIBRATOR

The calibration of radio frequency vacuum tube voltmeters has long been a major problem in the average standardizing laboratory. Providing a stable and known voltage well up into the megacycle range has been a somewhat uncertain procedure. Most previous calibration methods have depended upon the long term stability of a comparison voltmeter or special amplifier units. These methods suffer from variations with time because tube or transistor characteristics change during their useful life and vary markedly from unit to unit when replaced. One of the most fundamental methods of making such calibrations is that of using a thermocouple and resistance network which can be checked on DC and then on AC. Such a system is inherently limited only only by the resistor network itself and its frequency response.


RF INPUT
± LOW
±LOW
TEMPORARY CONNECTION FOR CALIBRATION
SHIELDED CABLE
2 OHMS
.01 V.
18 OHMS
.1 V.
180 OHMS
1 V.
320 OHMS
3 V. STANDARD D.C. REFERENCE SOURCE
+
−
80 OHMS 5 MA. THERMO COUPLE
.01 V.
.1V.
1V.
3V.
3 V.
TEMPORARY CONNECTION FOR CALIBRATION

INTERNAL CIRCUIT OF R.F. VOLTAGE CALIBRATOR

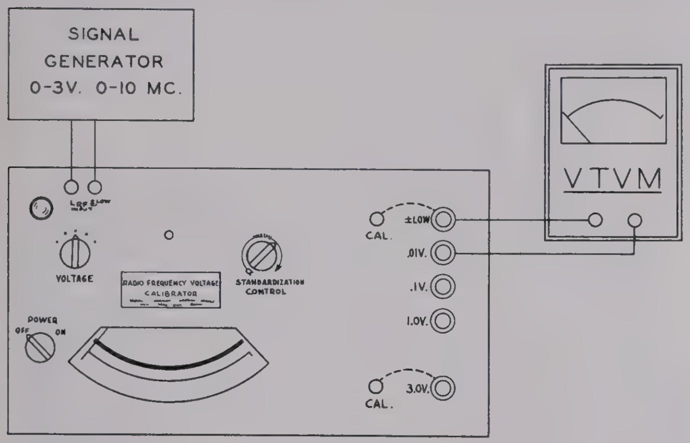
Fig. 1

The Sensitive Research Radio Frequency Voltage Calibrator is a thermal instrument combined with a non-frequency sensitive resistance divider network. Included within the equipment is a standardized DC reference source for the calibration of the network and thermocouple. This method provides a readily proveable voltage source for the calibration of vacuum tube voltmeters to well above 10 megacycles. The schematic diagram in figure 1 shows how this is accomplished. The heart of the instrument is seen to be a string of resistors in a voltage divider network with an ULTRA-HIGH frequency type thermocouple used to monitor the current through this network. The output of the thermocouple is read on a millivoltmeter; special compensation resistors are switched into the DC side for highest accuracy on each of the ranges involved. Also included is a shunt variable resistor for high accuracy calibration against the DC reference source at the time of use. This "time of use" calibration will remove any trace of error due to ambient temperature, possible overload of the thermocouple, or any other factors of this nature. The long term accuracy of the instrument is thus assured. In use, the resistance thermocouple network is first connected across the terminals of the three volt reference source. The full scale reading of the instrument is adjusted by means of the variable shunt resistance. All ranges are adjusted for full scale accuracy by means of a single "self check."

The temporary leads by means of which the DC was connected to the multiplier chain are removed and a sutiable signal generator is applied to the terminals marked "RF input." These terminals provide the driving voltage through a shielded internal connection to the "± low" and the "3 v. posts." The provision of these extra posts for the signal generator improve the overall accuracy by allowing the generator leads to be physically removed from the output connections, except through a shielded lead. The instrument to be calibrated is then connected to the binding posts with short direct leads to the "± low" and an appropriate terminal depending on the range of the instrument involved. These connections are shown on figure 2. The range is then turned to the position corresponding to the range of output voltage desired. This must, of course, agree with the binding post used in conjunction with the ± low post. The signal generator output controls are then used to adjust the instrument indication to the value required. Agreement with the scale calibration and the external vacuum tube voltmeter then determines the basic accuracy of the vacuum tube voltmeter at the frequency involved. The signal generator is varied both in output and frequency in steps as may be required to provide a complete calibration of the vacuum tube voltmeter. Several points should be discussed in regard to the actual construction and operation of this instrument as they are extremely significant in providing the wide range and high accuracy obtained. The resistors comprising the voltage divider network are extremely critical as far as their frequency response is concerned.

The lower values in the .01 volt and .1 volt ranges are obtained with very short lengths of straight wire. The resistors for the higher ranges are obtained by means of deposted noble metal alloy type resistors. These resistors are not critically adjusted by means of spiral grinding as is common in this type of resistor, as this tends to raise the inductance of such units. Instead, the final calibration is done by means of individual resistors in the DC side as selected by the range switch. This allows

RADIO FREQUENCY VOLTAGE CALIBRATOR



R.F. CALIBRATION SET-UP FOR VTVM

Fig. 2

the use of nominal value resistors in the voltage divider network chosen purely on the basis of their extreme frequency response and allows high accuracy in actual calibration of the instrument. The Model RFVC is, of course, primarily a voltage source. The impedance of the voltage divider is very low and as the input impedance of most vacuum tube voltmeters is relatively high, it can, in general, be considered a zero output resistance device. The actual resistances involved are approximately 2 ohms on the .01 range, 20 ohms on the .1, 200 ohms on the 1 volt and 600 ohms on the 3 volt ranges. Inasmuch as the entire divider network is used on the 3 volt range, any impedance instrument whatsoever can be used on the 3 volt range as this constitutes only a load on the signal generator. Values of 2000 ohms for the .01 volt range, 20,000 for the .1 volt range, and 200,000 ohms for the 1 volt range can be considered completely negligible for loading effects. Instruments with these impedances would cause only a .1% drop in the output voltage. This instrument is, of course, a true RMS responding instrument because of the use of the thermocouple. This will pose some problems in the calibration of vacuum tube voltmeters that have responses which are portional either to average or peak. Unless a truly sinusoidal generator is used, a knowledge of the wave shape of the generator and the response of the vacuum tube voltmeter is a "must" when discrepancies appear to arise in the calibration of instruments. In the case of a non-sinusoidal generator the vacuum tube voltmeter and the RFVC could disagree markedly because of their inherently different responses, even though both instruments were well within their normal operating accuracies. In using the .01 volt range particularly, it is extremely important that the vacuum tube voltmeter be connected to the terminal with very short direct leads, and that calibrations be performed in an area in which signal strengths are not extremely high, as pickup on these leads would provide vacuum tube voltmeter deflection in addition to the desired signal being produced by the RFVC.

These factors are ordinarily not major factors because the RFVC output impedance is so low in value. The accuracy of this instrument is guaranteed to be within ½% at frequencies up to 10 megacycles, with the exception of the .01 volt range which because of the possibilities of errors due to pickup on leads, carries an increased tolerance of 1%. The use of the Sensitive Research Model RFVC will provide a simple, fast, and accurate method of certifying vacuum voltmeters with responses up to 10 megacycles in the range of approximately 2 millivolts up to 3 volts. The instrument operates from a 115 volt 60 cycle source drawing approximately 25 watts to supply a DC reference network.

SPECIFICATIONS

HORIZONTAL USE ONLY

SCALE LENGTH	6.3 inches
SCALE DIVISIONS	100
ACCURACY	.5% to 10 megacycles except .010 v. range which is 1%
SIZE	16⅜" x 10½" x 8¾"
INST. WEIGHT	21 pounds
SHIP. WEIGHT	45 pounds

RADIO FREQUENCY VOLTAGE CALIBRATOR

Full Scale Ranges	Lowest Calibrated Point	Code Word	Price
0 - .01 - .1 - 1 - 3 volts	2 millivolts	RFVCON	$840.00

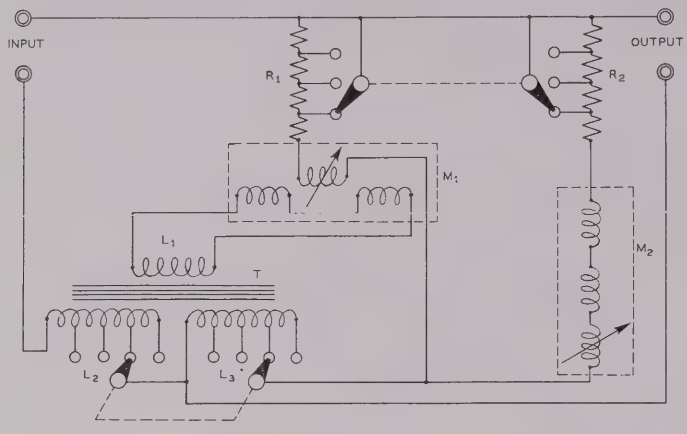
Supplied in Formica Case

Model RFVCEW-7 This RF Voltage Calibrator available as an edgewise panel instrument mounted on a 19" x 8¾" x 5/16" black bakelite panel. $840.00

Prices and specifications are subject to change without notice.

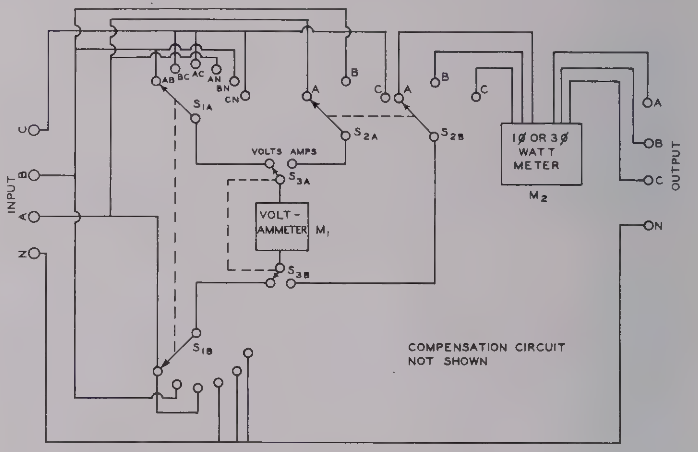
THREE PHASE VOLT-AMP-WATTMETER

Sensitive Research has for a good many years produced their Model VAW, a single phase power measuring instrument. This instrument has proved to be extremely satisfactory for the measurement of low power AC devices, measuring voltage, current, and power from an input circuit through to a load circuit with all the readings completely compensated for instrument losses, thus providing tare free readings of the load being measured. The 3 phase VOLT-AMP-WATTMETER now extends this simplicity of measurement into the 2 phase and 3 phase power field. The basic method of compensating the instrument readings is shown in Figure 3. This is the single phase version and shows that the potential circuit of the wattmeter and the voltmeter are so returned that the current which they draw is fed through a separate compensating winding on the instrument transformer feeding the fields of the wattmeter. The phase relation of this winding is such that the current being drawn by the potential circuit of the wattmeter and the voltmeter passing through this winding, which has an equal number of turns to the regular load current winding but in an opposite direction, cancels out the effect of this current in the field circuit of the wattmeter. For reading 3 phase power, of course, the 3 phase model TPW uses a two element wattmeter and this compensation circuit is doubled and applied to each element of the wattmeter. The basic circuitry of the three phase instrument is shown in Figure 4. In order to make the circuit less complicated a separate voltmeter-ammeter instrument is used in the 3 phase version. This is switched as shown in Figure 4 for use as a voltmeter across any possible combination of three or four wire circuits in order to read voltage or as an ammeter in any line to read current. An additional compensation circuit which is not shown simultaneously provides impedances equal to the voltmeter across the 2 unmetered legs of the 3 phase circuit. This insures that the voltmeter loading will at no time tend to unbalance the circuit. The instrument, as an ammeter, can be switched into any one of the 3 phase circuits and will also have a set of compensating resistors in each unmetered leg. The wattmeter which can be used as either a single or 3 phase instrument will read total power in any three wire circuit, be it balanced or unbalanced, 2 phase or 3 phase. Blondell's theorem states that in any circuit in which a load is supplied by N wires that N-1 wattmeters will provide accurate measurements of total power. The instrument carries a 4 wire circuit through from both input to output. However, the wattmeter will read accurately the total power only in a balanced circuit when used with 4 wire connections. The instrument provides for voltage ranges of 0 to 100, 0 to 200, and 0 to 500 volts. Ampere ranges provided are .5 ampere, 1 ampere, 5 amperes, and 10 amperes. Watt ranges are determined by the setting of the volt switch and the ampere switch. The watt readings for any combination of settings will be the product of the volt range and the ampere range. This gives watt ranges of 50, 100, 200, 250 and 500 watts, and 1 kilowatt, 2 kilowatts, 2.5 kilowatts, and 5 kilowatts. The 3 phase volt-amp-wattmeter has a frequency response satisfactory for use from 50 to 500 cycles. The voltmeter and ammeter are full accuracy over this entire frequency range. The wattmeter at or near 100% power factor has full accuracy over the entire range. However, when used at power factors of 50% which is the lower limit for use, it will maintain full accuracy in the range from 50 to 125 cycles and will decrease in accuracy to 1½% at 500 cycles. The advantage of having all the readings of an instrument of this type being completely compensated for instrument power cannot be over estimated. A collection of instruments such as is involved in the 3 phase volt-amp-wattmeter draw appreciable power. However, with a compensation method such as used in this instrument all of this power represents a load upon the source and the power consumed does not appear in the instrument reading. The values read for volts, amperes, and watts are those of the load alone, no computation or corrections being required for any reading whatsoever. The speed and versatility of such an instrument is very markedly better than any possible combination of individual instruments.



BASIC COMPENSATION CIRCUIT

Fig. 3



3 PHASE VAW CIRCUIT

Fig. 4

Full Scale Ranges

VOLTS	0 - 100/200/500 (100 ohms per volt)
AMPERES	0 - .5/1/5/10
WATTS	0 - 50/100/200/250/500/1000/2000/2500/5000

Prices and specification are subject to change without notice.

FREQUENCY	For use at 50 - 500 cycles
SCALE	5.2 inches
SIZE	22" x 14½" x 9½" (Formica Case)
WEIGHT	Approx. 40 lbs.
CODE	WATTAVOLT
PRICE	$2735.00

Printed in U.S.A.

Electrical MEASUREMENTS

VOLUME 28 JUNE, 1961 NUMBER 6

MODEL RFVC

RADIO FREQUENCY
VOLTAGE
CALIBRATOR

ACCURACY

.5% to 10 megacycles
except .010 v. range
which is 1%.

MODEL TPW

THREE PHASE
VOLT-AMP-
WATTMETER

ACCURACY

Watts — ½%
Volts — ¼%
Amperes — ¼%

For use at 50 - 500 cycles

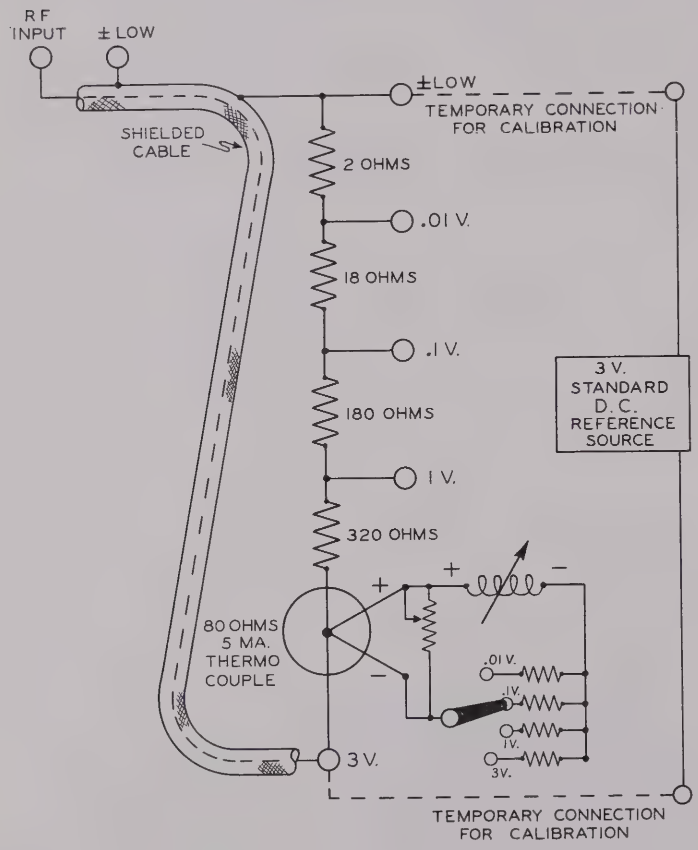
**SENSITIVE RESEARCH
INSTRUMENT CORPORATION**

NEW ROCHELLE, N. Y. *ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927*

Symbol of Quality

RADIO FREQUENCY VOLTAGE CALIBRATOR

The calibration of radio frequency vacuum tube voltmeters has long been a major problem in the average standardizing laboratory. Providing a stable and known voltage well up into the megacycle range has been a somewhat uncertain procedure. Most previous calibration methods have depended upon the long term stability of a comparison voltmeter or special amplifier units. These methods suffer from variations with time because tube or transistor characteristics change during their useful life and vary markedly from unit to unit when replaced. One of the most fundamental methods of making such calibrations is that of using a thermocouple and resistance network which can be checked on DC and then on AC. Such a system is inherently limited only only by the resistor network itself and its frequency response.


RF INPUT
± LOW
±LOW
TEMPORARY CONNECTION FOR CALIBRATION
SHIELDED CABLE
2 OHMS
.01 V.
18 OHMS
.1 V.
3 V. STANDARD D.C. REFERENCE SOURCE
180 OHMS
1 V.
320 OHMS
+
+
−
80 OHMS 5 MA. THERMO COUPLE
−
.01 V.
.1V.
1V.
3V.
3 V.
TEMPORARY CONNECTION FOR CALIBRATION

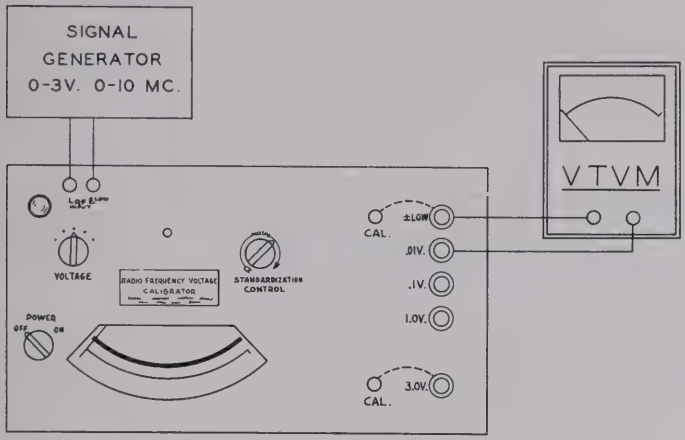
INTERNAL CIRCUIT OF
R.F. VOLTAGE CALIBRATOR

Fig. 1

The Sensitive Research Radio Frequency Voltage Calibrator is a thermal instrument combined with a non-frequency sensitive resistance divider network. Included within the equipment is a standardized DC reference source for the calibration of the network and thermocouple. This method provides a readily proveable voltage source for the calibration of vacuum tube voltmeters to well above 10 megacycles. The schematic diagram in figure 1 shows how this is accomplished. The heart of the instrument is seen to be a string of resistors in a voltage divider network with an ULTRA-HIGH frequency type thermocouple used to monitor the current through this network. The output of the thermocouple is read on a millivoltmeter; special compensation resistors are switched into the DC side for highest accuracy on each of the ranges involved. Also included is a shunt variable resistor for high accuracy calibration against the DC reference source at the time of use. This "time of use" calibration will remove any trace of error due to ambient temperature, possible overload of the thermocouple, or any other factors of this nature. The long term accuracy of the instrument is thus assured. In use, the resistance thermocouple network is first connected across the terminals of the three volt reference source. The full scale reading of the instrument is adjusted by means of the variable shunt resistance. All ranges are adjusted for full scale accuracy by means of a single "self check."

The temporary leads by means of which the DC was connected to the multiplier chain are removed and a sutiable signal generator is applied to the terminals marked "RF input." These terminals provide the driving voltage through a shielded internal connection to the "± low" and the "3 v. posts." The provision of these extra posts for the signal generator improve the overall accuracy by allowing the generator leads to be physically removed from the output connections, except through a shielded lead. The instrument to be calibrated is then connected to the binding posts with short direct leads to the "± low" and an appropriate terminal depending on the range of the instrument involved. These connections are shown on figure 2. The range is then turned to the position corresponding to the range of output voltage desired. This must, of course, agree with the binding post used in conjunction with the ± low post. The signal generator output controls are then used to adjust the instrument indication to the value required. Agreement with the scale calibration and the external vacuum tube voltmeter then determines the basic accuracy of the vacuum tube voltmeter at the frequency involved. The signal generator is varied both in output and frequency in steps as may be required to provide a complete calibration of the vacuum tube voltmeter. Several points should be discussed in regard to the actual construction and operation of this instrument as they are extremely significant in providing the wide range and high accuracy obtained. The resistors comprising the voltage divider network are extremely critical as far as their frequency response is concerned.

The lower values in the .01 volt and .1 volt ranges are obtained with very short lengths of straight wire. The resistors for the higher ranges are obtained by means of deposted noble metal alloy type resistors. These resistors are not critically adjusted by means of spiral grinding as is common in this type of resistor, as this tends to raise the inductance of such units. Instead, the final calibration is done by means of individual resistors in the DC side as selected by the range switch. This allows the use of nominal value resistors in the voltage divider network chosen purely on the basis of their extreme frequency response and allows high accuracy in actual calibration of the instrument. The Model RFVC is, of course, primarily a voltage source. The impedance of the voltage divider is very low and as the input impedance of most vacuum tube voltmeters is relatively high, it can, in general, be considered a zero output resistance device. The actual resistances involved are approximately 2 ohms on the .01 range, 20 ohms on the .1, 200 ohms on the 1 volt and 600 ohms on the 3 volt ranges. Inasmuch as the entire divider network is used on the 3 volt range, any impedance instrument whatsoever can be used on the 3 volt range as this constitutes only a load on the signal generator. Values of 2000 ohms for the .01 volt range, 20,000 for the .1 volt range, and 200,000 ohms for the 1 volt range can be considered completely negligible for loading effects. Instruments with these impedances would cause only a .1% drop in the output voltage. This instrument is, of course, a true RMS responding instrument because of the use of the thermocouple. This will pose some problems in the calibration of vacuum tube voltmeters that have responses which are portional either to average or peak. Unless a truly sinusoidal generator is used, a knowledge of the wave shape of the generator and the response of the vacuum tube voltmeter is a "must" when discrepancies appear to arise in the calibration of instruments. In the case of a non-sinusoidal generator the vacuum tube voltmeter and the RFVC could disagree markedly because of their inherently different responses, even though both instruments were well within their normal operating accuracies. In using the .01 volt range particularly, it is extremely important that the vacuum tube voltmeter be connected to the terminal with very short direct leads, and that calibrations be performed in an area in which signal strengths are not extremely high, as pickup on these leads would provide vacuum tube voltmeter deflection in addition to the desired signal being produced by the RFVC.



R.F. CALIBRATION SET-UP FOR VTVM

Fig. 2

These factors are ordinarily not major factors because the RFVC output impedance is so low in value. The accuracy of this instrument is guaranteed to be within ½% at frequencies up to 10 megacycles, with the exception of the .01 volt range which because of the possibilities of errors due to pickup on leads, carries an increased tolerance of 1%. The use of the Sensitive Research Model RFVC will provide a simple, fast, and accurate method of certifying vacuum voltmeters with responses up to 10 megacycles in the range of approximately 2 millivolts up to 3 volts. The instrument operates from a 115 volt 60 cycle source drawing approximately 25 watts to supply a DC reference network.

SPECIFICATIONS

HORIZONTAL USE ONLY

SCALE LENGTH	6.3 inches
SCALE DIVISIONS	100
ACCURACY	.5% to 10 megacycles except .010 v. range which is 1%
SIZE	16⅜" x 10½" x 8¾"
INST. WEIGHT	21 pounds
SHIP. WEIGHT	45 pounds

RADIO FREQUENCY VOLTAGE CALIBRATOR

Full Scale Ranges	Lowest Calibrated Point	Code Word	Price
0 - .01 - .1 - 1 - 3 volts	2 millivolts	RFVCON	$840.00

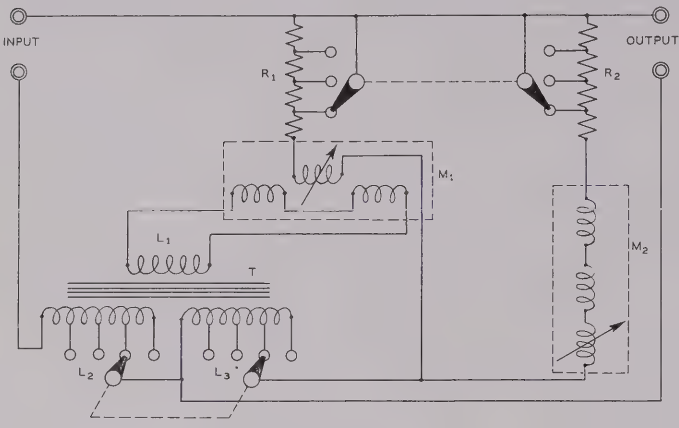
Supplied in Formica Case

Model RFVCEW-7 This RF Voltage Calibrator available as an edgewise panel instrument mounted on a 19" x 8¾" x $\frac{5}{16}$" black bakelite panel. $840.00

Prices and specifications are subject to change without notice.

THREE PHASE VOLT-AMP-WATTMETER

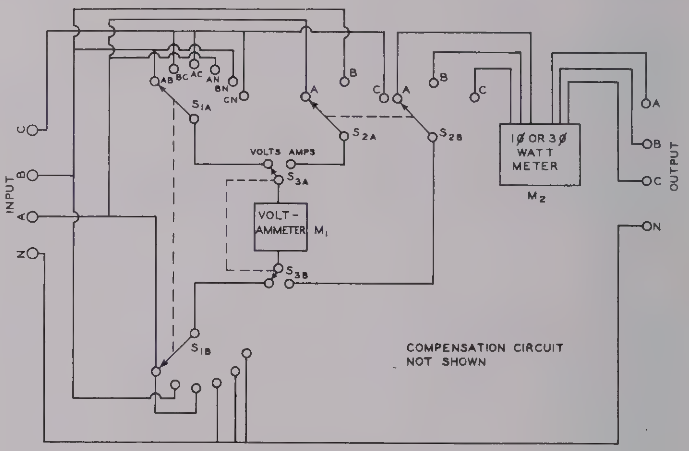
Sensitive Research has for a good many years produced their Model VAW, a single phase power measuring instrument. This instrument has proved to be extremely satisfactory for the measurement of low power AC devices, measuring voltage, current, and power from an input circuit through to a load circuit with all the readings completely compensated for instrument losses, thus providing tare free readings of the load being measured. The 3 phase VOLT-AMP-WATTMETER now extends this simplicity of measurement into the 2 phase and 3 phase power field. The basic method of compensating the instrument readings is shown in Figure 3.



BASIC COMPENSATION CIRCUIT

Fig. 3

This is the single phase version and shows that the potential circuit of the wattmeter and the voltmeter are so returned that the current which they draw is fed through a separate compensating winding on the instrument transformer feeding the fields of the wattmeter. The phase relation of this winding is such that the current being drawn by the potential circuit of the wattmeter and the voltmeter passing through this winding, which has an equal number of turns to the regular load current winding but in an opposite direction, cancels out the effect of this current in the field circuit of the wattmeter. For reading 3 phase power, of course, the 3 phase model TPW uses a two element wattmeter and this compensation circuit is doubled and applied to each element of the wattmeter. The basic circuitry of the three phase instrument is shown in Figure 4. In order to make the circuit less complicated a separate voltmeter-ammeter instrument is used in the 3 phase version. This is switched as shown in Figure 4 for use as a voltmeter across any possible combination of three or four wire circuits in order to read voltage or as an ammeter in any line to read current. An additional compensation circuit which is not shown simultaneously provides impedances equal to the voltmeter across the 2 unmetered legs of the 3 phase circuit. This insures that the voltmeter loading will at no time tend to unbalance the circuit. The instrument, as an ammeter, can be switched into any one of the 3 phase circuits and will also have a set of compensating resistors in each unmetered leg. The wattmeter which can be used as either a single or 3 phase instrument will read total power in any three wire circuit, be it balanced or unbalanced, 2 phase or 3 phase. Blondell's theorem states that in any circuit in which a load is supplied by N wires that N-1 wattmeters will provide accurate measurements of total power. The instrument carries a 4 wire circuit through from both input to output. However, the wattmeter will read accurately the total power only in a balanced circuit when used with 4 wire connections. The instrument provides for voltage ranges of 0 to 100, 0 to 200, and 0 to 500 volts. Ampere ranges provided are .5 ampere, 1 ampere, 5 amperes, and 10 amperes. Watt ranges are determined by the setting of the volt switch and the ampere switch. The watt readings for any combination of settings will be the product of the volt range and the ampere range. This gives watt ranges of 50, 100, 200, 250 and 500 watts, and 1 kilowatt, 2 kilowatts, 2.5 kilowatts, and 5 kilowatts. The 3 phase volt-amp-wattmeter has a frequency response satisfactory for use from 50 to 500 cycles. The voltmeter and ammeter are full accuracy over this entire frequency range. The wattmeter at or near 100% power factor has full accuracy over the entire range. However, when used at power factors of 50% which is the lower limit for use, it will maintain full accuracy in the range from 50 to 125 cycles and will decrease in accuracy to 1½% at 500 cycles.



3 PHASE VAW CIRCUIT

Fig. 4

The advantage of having all the readings of an instrument of this type being completely compensated for instrument power cannot be over estimated. A collection of instruments such as is involved in the 3 phase volt-amp-wattmeter draw appreciable power. However, with a compensation method such as used in this instrument all of this power represents a load upon the source and the power consumed does not appear in the instrument reading. The values read for volts, amperes, and watts are those of the load alone, no computation or corrections being required for any reading whatsoever. The speed and versatility of such an instrument is very markedly better than any possible combination of individual instruments.

	Full Scale Ranges
VOLTS	0 - 100/200/500 (100 ohms per volt)
AMPERES	0 - .5/1/5/10
WATTS	0 - 50/100/200/250/500/1000/2000/2500/5000

Prices and specification are subject to change without notice.

FREQUENCY	For use at 50 - 500 cycles
SCALE	5.2 inches
SIZE	22" x 14½" x 9½" (Formica Case)
WEIGHT	Approx. 40 lbs.
CODE	WATTAVOLT
PRICE	$2735.00

Printed in U.S.A.

Electrical
MEASUREMENTS

VOLUME 28 MAY, 1961 NUMBER 5

MUCH ABOUT LITTLE DIFFERENCES!

MODEL
LTC - I

Accuracy
.05% of Any Reading

AC/DC CALIBRATION CONSOLE

In previous issues we have explained in detail the derivation and maintenance of satisfactory DC standards. In this issue, we describe a more difficult problem, which is the derivation and maintenance of satisfactory AC standards.

A standards engineer would readily give much for a satisfactory AC standard cell, one that would have long term stabilities in the order of 2 or 3 parts per million comparable with that obtained in the ordinary DC saturated cell when maintained in a constant temperature cabinet.

Unfortunately, no such thing exists. All of our AC measurements are referred back in some manner to the basic standard of voltage, the saturated DC cell. All really HIGH ACCURACY AC measurements are essentially TRANSFER measurements. Many different methods and types of equipment are used for these AC - DC transfers.

The simplest, of course, is to use an instrument which is inherently RMS responding and use it as a transfer device between a high accuracy DC reference source and the AC to be measured. Such a circuit is shown in Fig. I.

In order to measure the AC voltage "X," we use a transfer standard instrument to interpolate between the DC reference standard and the AC voltage. The transfer instrument is first switched to position B and a reading obtained.

SENSITIVE RESEARCH
INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

Symbol of Quality

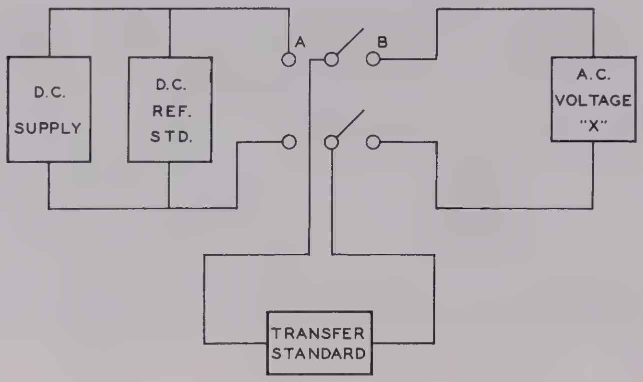


Fig. No. 1

The switch is then transferred to the A position and the DC supply adjusted to bring the instrument to the exact same point. When the instrument indicates that the AC and DC voltages are identical, the DC reference standard is then read for the actual value of the DC voltage.

Assuming the transfer standard to be perfect, then the DC reference standard voltage is equal to the AC voltage "X." Taking a closer look at this we find several possibilities of error. We have, of course, the inherent error of loading of the transfer standard instrument in measuring the value "X."

This is common in all measurements, AC or DC, in which a power consuming device is required. Unfortunately, for high stability accurate measurements, we have no type of transfer standard which is not a power consuming device. This error, however, can be known to a high degree of certainty and allowance made for it.

We next have the possibility of error in the AC - DC transfer characteristics of the instrument itself. This error has to be investigated individually for the various types of transfer standards, which may be used.

There are three common types of transfer standards. The dynamometer instrument, the thermal instrument, and the electrostatic instrument. In the case of the dynamometer instrument, the AC - DC agreement runs into difficulty because of the inductance of the windings.

The dynamometer instrument can be made a satisfactory transfer instrument only for relatively low frequencies because of the effect of the inductance and distributed capacitance of its windings.

Let us look at the electrostatic instrument. Theoretically, the electrostatic instrument is a very satisfactory transfer device, up to quite high frequencies.

The theoretical limitations are those in which its mechanical dimensions become an appreciable fraction of a wave length. This limits the high frequency response of the instrument. It is also limited at those frequencies where its insulating materials become less than satisfactory. These frequency limitations, however, are far less severe than those of the dynamometer.

Unfortunately, the electrostatic does have one limitation to its use. Its basic sensitivity is poor and hence, it cannot be made for use at low voltages. The use of the electrostatic instrument as an accurate device is limited in general to voltages of several hundred volts or more in order to have a satisfactory torque to weight ratio for its moving element.

It is fairly obvious from the discussion so far, that we are bringing ourselves to the use of a thermal instrument. The thermal instrument is inherently an RMS responding instrument. The heater can be a relatively straight line, low inductance, low capacitance device and consume relatively little power by comparison to the dynamometer. Hence, it is as nearly an ideal transfer device as we can obtain.

The thermal transfer standard method is the most commonly used, except at power frequencies where the dynamometer is used because of its ruggedness.

The dynamometer instrument can be made satisfactory for transfer work to an accuracy of 1/10% or possibly somewhat better. One of the limitations of this instrument is that of its DC reversal characteristics.

When a dynamometer instrument is used on DC it is usually considered that its deflection bears no relation to the direction of flow of current. This is only approximately true and all commercially available instruments show at least some DC "reversal" effect in which the deflections are not identical when the DC voltage or current is reversed.

This usually necessitates Fig. 1 being modified to include a DC reversal switch for the DC supply and the DC reference standard. The assumption is then made that the average of the two reversed DC readings should be equal to the AC value. This is a satisfactory assumption, if the DC reversal effect is not too great.

Large DC reversals cannot be tolerated on instruments for this use, because the mean of the reversed DC readings presupposes that all of the factors involved are linear, an assumption which is not warranted with careful examination. The other two types of transfer instrument (the thermal and electrostatic) suffer to some lesser extent from this DC reversal effect.

In the case of the electrostatic, the effect becomes fairly pronounced on instruments at extremely high voltages due primarily to polarization effects in the insulators involved.

In the case of the thermal transfer unit, these reversal effects can be made very small by careful attention to the thermal junctions themselves, and in fact, thermal junctions are commercially available at this time from us with guaranteed DC reversal effects of not more than .01%.

With such tiny amounts of DC reversal, the assumption of linearity which allows the "mean" of DC values to equal the AC value introduces a completely negligible error.

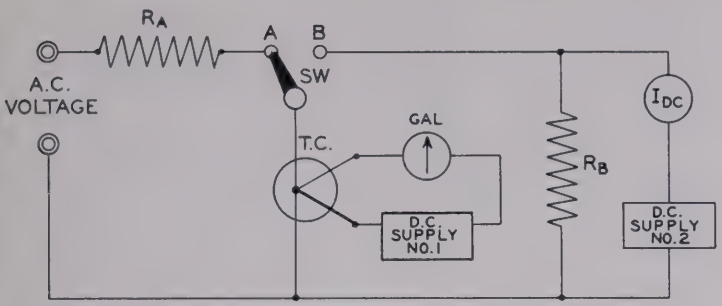
Actually, for a great majority of measurements a single DC value can be assumed and the reversal effect with its possible error of half the reversal or .005% completely disregarded.

In the use of a thermal transfer standard many circuits and arrangements may be used. However, the simplest and best is that devised by Francis L. Hermach of the Bureau of Standards, which has been adopted by SENSITIVE RESEARCH in their line of AC - DC test consoles.

The basic circuitry of the voltage transfer system is repeated in Fig. 2. Very complete discussions of this circuit have been given by both ourselves and other people and we will not elaborate to any great extent at this writing, except to quote the obvious advantages of such a circuit.

It is seen in Fig. 2 that when the transfer is made from the AC volt position to the DC substitution position, a resistor RB is shunted across the thermocouple in the DC sub position this resistor having exactly the same value as the series resistance RA used in the AC voltage position.

When the mathematics of this are followed through, it is seen that Vac or the applied AC voltage is equal to Idc X RA or RB, (they are identical). In other words, the thermocouple calibration constants and all other factors wash out of the picture entirely and the transfer is purely in terms of the measurement of a DC current and the value of a known resistance.



BASIC A.C.-D.C. VOLTAGE
TRANSFER CIRCUIT

Fig. No. 2

The thermocouple is required to have only short term stability, (not change its value during the course of the transfer) and the method of measuring the thermocouple output be of sufficient sensitivity to detect very small differences.

SRIC is currently producing a new console, (the Model LTC-1). This is the second version of an elaborate test console in which RA and RB are a series of decade resistors which allow any value from .5 volt to 1100 volts to be set up as the test point.

The current measurement of Idc is made with the well known SENSITIVE RESEARCH INCREMETER instrument. With this circuitry we take advantage of the Hermach circuit which allows the DC substitution current to be of a single constant value regardless of the range of operation. Because of this single point operation the INCREMETER is used at a single reference point and can be calibrated directly in terms of percentage error of that point.

The Model LTC-1 contains several logical improvements over the preceding LTC. The first and most noticeable improvement is that of basic appearance, the instrument is now housed in an attractive grey aluminum case. That provides a really striking appearance. It has its own integral panel lighting.

While the appearance is a factor, the major reason for the metal case is to provide superior shielding. In some locations where there are extremely high level VHF signals there is a possibility of some signal pick-up by the internal wiring which the metal cabinet completely eliminates.

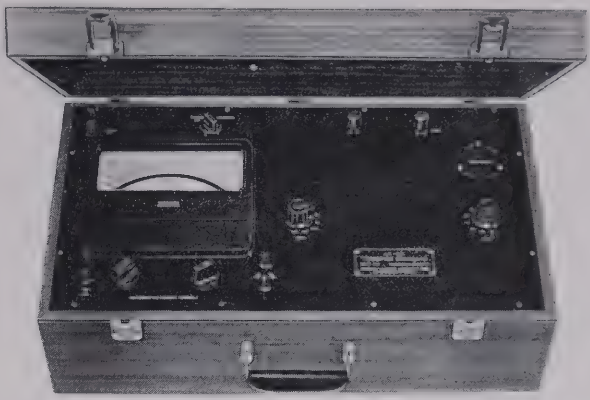
An improved galvanometer has been installed which allows more rapid readings and greater immunity to shock and vibration.

A slight re-arrangement of controls has been made which will allow for a somewhat smoother operation. All of the electrical circuitry involved is the same as the basic unit that has proven so satisfactory in field operation (our Model LTC).

The only basic electrical change in the entire instrument is a provision for potentiometric read out when required in place of the much more rapid incremeter error indicator on the front of the panel. In those cases where users require a very high degree of resolution for the inter-comparison of voltags or the detection of very small differences, a link on the back is provided where a potentiometer can be connected.

In this operation, the potentiometer will read exactly one volt for zero error and proportionate amounts high or low depending on the actual deviation from one volt. This allows for much greater resolution although the basic accuracy is not appreciably increased.

The LTC-1 successor to our Model LTC remains the widest range and most flexible test set available for relatively high speed calibration of an extremely wide range of AC and DC instruments.



MODEL FLH

AC/DC TRANSFER STANDARD

The Model LTC-1 being a commercial calibration console has of necessity some tolerances which are unavoidable in making such an instrument. The internal reference supply, the accuracy of adjustment of a large number of decade resistors and factors of this general nature give an overall accuracy conservatively rated at .05%.

A logical question is "how much farther is it possible to go?" In most standards work higher accuracy means the simplest most fundamental approach to the measurement, allowing the fewest steps between your standard and the instrument being measured.

This, of course, brings us back to Fig. 1. If, in Fig. 1, our reference DC standard is composed of the highest accuracy potentiometer we can obtain, the highest accuracy volt box and the highest accuracy saturated standard cell reference, we have then the best obtainable DC voltage standard. If to this we add an AC - DC transfer standard with the best available AC - DC differences, we will then be able to transfer our AC voltage "X" to our DC standards with a minimum of operations and hence, a minimum of inaccuracies.

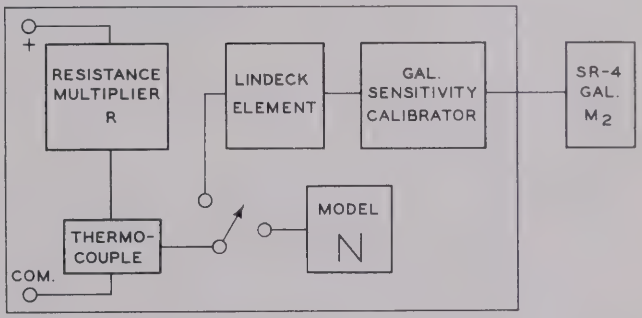


Fig. No 3

Such a transfer standard is our newly designed Model FLH. This is a high accuracy AC - DC difference test instrument or transfer standard. Fig. 3 shows the basic elements. With the switch thrown to the position connecting the indicating instrument, it creates a simple thermocouple type voltmeter. It is simple in that the circuitry is identical with that of our thermocouple voltmeters.

However, in this particular instrument the resistance multipliers have been designed purely on a basis of frequency response without the usual compromises to long term stability. The resistors and the range switch have frequency response well up into the megacycle range. Hence, to frequencies in the order of 30 kilocycles, the error due to AC - DC difference will be COMPLETELY NEGLIGIBLE.

The thermocouple used is housed in a position where it cannot change temperature rapidly and hence, the short term stability is excellent. All this means that the thermal element and the indicator instrument constitue an AC - DC transfer unit in which the actual AC to DC errors will be very small and the accuracy with which in AC measurement may be transferred to DC or vice-versa, is limited only by the ability to read the pointer of the instrument. To cure this deficiency we can switch to the Lindeck position.

In this position a very high resolution Lindeck element is used to provide a millivolt output which is made EQUAL and OPPOSITE to the output of the thermocouple. Ability to read this output is limited entirely to the sensitivity of the galvanometer to detect differences between the Lindeck element and the thermocouple output.

This sensitivity with our Model SR4 galvanometer normally furnished with the instrument is ample to show differences in the order of .002% or .003%. This difference shows up as a galvanometer deflection when the instrument is first zeroed in the DC position and then thrown to the AC position or vice versa. To calibrate this galvanometer deflection and make its value known in terms of actual percentage difference, two special calibration keys are provided on the Model FLH, one of which gives a deliberate downward shift in the output of .1% and the other a deliberate downward shift of .01%.

Pressing these keys provide immediate calibration of the instrument at the actual time of use. This unit, the Model FLH is to be available only with a National of Bureau's standard as to the actual AC - DC errors. The certificate values provided by NBS will allow an overall AC - DC difference accuracy of .01% or better.

The total errors in an AC voltage measurement then become something in this order of magnitude. For a SRIC Commander Type 9144 Potentiometer, .001%, another .001% for SRIC Commander 9700, or 9700A Volt Box and a third, .001% for a 9152 Constant Temperature Standard Cell Enclosure. This then is a total possible DC error of .003%, a value which in all probability would be markedly better in normal operation and to this would then be added the .01% of the Model FLH. The sum total would then reach the very satisfactory figure of .013% maximum possible error of the AC measurement. This is about the best that it is possible to do with actual certificated values on all of the instruments.

In actual practice accuracies of 2 to 3 times this will probably be obtained, but do not become legally provable. This, as anyone familiar with the techniques involved will realize, will be a somewhat slow, laborious method of meauring AC voltages. But it DOES produce the highest possible accuracies and it is actually the method used for the certification and calibration of the Model LTC-1 console.

The above Model FLH description has been based on voltage measurements which have provided the greatest difficulty in this range of accurate standards. An exact corollary for everything that has been stated can be made in terms of current. A simple multirange current version of the Model FLH voltage transfer standard will be available soon from SRIC.

In the meantime, the same basic system can be used, using individual thermocouples as current transfer devices with external Lindeck elements and galvanometers as detection devices. All our readers will be notified as soon as the commercial current version of the instrument has completed its test requirements and is ready for market. In the opening paragraph of this bulletin we used the term derivation of AC standards and measurements. As can be plainly seen from the lengthy dissertation between that paragraph and this, there are no AC standards. There are only means of transferring AC measurements to DC standards with their inherent accuracy and long term stability.

AC/DC CALIBRATION CONSOLE

MODEL LTC-1

ACCURACY:	± .05% of reading
AC/DC RANGES:	2 ma - 11.10 amperes in steps of 1 ma; .5 v - 1110 v in steps of .1 v
DC RANGES:	1 ma - 11.10 amperes in steps of 1 ma; .5 v - 1110 v in steps of .1 v
SENSITIVITY:	AC/DC, 100 ohms per volt; DC, 1000 ohms per volt All current ranges have a 2 v potential drop.
FREQUENCY RANGE:	.5 - 99 volts, DC - 25,000 cycles; 100 - 199 volts, DC - 20,000 cycles; 200 - 399 volts, DC - 12,500 cycle; 400 - 1110 volt, DC - 2,500 cycles; .002 - .499 ampere, DC - 20,000 cycles .500 - 1.99 amperes, DC - 10 kc; 2.00 - 11.10 amperes, DC - 5 kc. Lowest practical frequency for full accuracy is 10 cps.
READOUT:	Directly in "% Error" (+5%–0–5%) or in actual values.
POWER REQUIRED: (Not Supplied)	115 v 60 cycle source; two 6 volt storage batteries for DC current; and a regulated 1000 v DC power supply.
	Model LT-PS-1 power supply is available on separate order. It is an AC source capable of supplying up to 1000 volts or 10 amperes (50 va total), over a variable frequency range (20 cps - 20 kc), with low distortion (.1% - .25% max.) and high short term amplitude stability (± .01%).
SIZE:	36" left to right x 28" high x 20" deep.
WEIGHT:	125 lbs.
SHIPPING WEIGHT:	175 lbs.
PRICE:	$5,560.00
TERMS:	Net 30 days f.o.b., New Rochelle, New York

The calibration of all Sensitive Research instruments is directly traceable to the National Bureau of Standards in Washington, D. C. or Boulder, Colorado. Unless otherwise stated, warranty is for a period of one year.

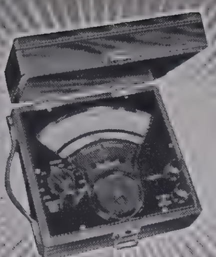
AC/DC TRANSFER STANDARD

MODEL FLH

ACCURACY:	± .01%* of reading from 25 cps to 30 kc with NBS correction figures; ± .05% of reading or better without correction figures. NBS correction figures to ± .01%* accuracy to 50 kc may be procured by special arrangement. Correspondence required. *.01% Accuracy Certificates available from NBS approximately Nov. 1, 1961, presently calibrations at .02% accuracy.
RANGES:	1.5 - 3/7.5/15/30/75/150/300/750 v. (Ranges may be used from 50 - 150% of nominal value. Total measuring range is, therefore, 1.5 - 1125 volts.)
FREQUENCY RANGE:	DC 25 cps to 50 kc.
SENSITIVITY:	100 ohms per volt (approximately).
RESOLUTION:	.005%
GALVANOMETER: SENSITIVITY:	.002 μa /mm. Our Commander Type SR4 Galvanometer furnished will deflect approximately 2 mm for a ± .01% AC/DC difference. Our Type 5214 Photocell Amplifier and Type SR21 Galavanometer can be substituted to give a 100 mm deflection, minimum.
CASE:	Portable formica case with hinged cover.
SIZE:	21¼" x 13" x 6$\frac{9}{16}$"
WEIGHT:	25 lbs.
SHIPPING WEIGHT:	45 lbs.
PRICE:	$1,685.00 (Includes *NBS Certificate and Type SR4 Galvanometer). If 5214 Amplifier and SR21 Galvanometer are desired, price is then $2,395.00.
TERMS:	Net 30 days f.o.b., NBS, Washington, D. C.

The Model FLH is guaranteed to maintain the stability of its frequency response indefinitely provided it is not physically or electrically abused. All parts and labor are warranted for a period of one year.

†See "COMMANDER" Catalog "A Brochure of Electrical Measuring Standards." Pg. 1 (Type 9144), Pg. 4 (Type 4305), PPg. 5 (Type 9700 & 9152), Pg. 6 (Types 5214 & SR21), a copy of which is yours for the asking.



Electrical
MEASUREMENTS

VOLUME 28 MAY, 1961 NUMBER 5

MUCH ABOUT LITTLE DIFFERENCES!

MODEL
LTC - 1

Accuracy
.05% of Any Reading

AC/DC CALIBRATION CONSOLE

In previous issues we have explained in detail the derivation and maintenance of satisfactory DC standards. In this issue, we describe a more difficult problem, which is the derivation and maintenance of satisfactory AC standards.

A standards engineer would readily give much for a satisfactory AC standard cell, one that would have long term stabilities in the order of 2 or 3 parts per million comparable with that obtained in the ordinary DC saturated cell when maintained in a constant temperature cabinet.

Unfortunately, no such thing exists. All of our AC measurements are referred back in some manner to the basic standard of voltage, the saturated DC cell. All really HIGH ACCURACY AC measurements are essentially TRANSFER measurements. Many different methods and types of equipment are used for these AC - DC transfers.

The simplest, of course, is to use an instrument which is inherently RMS responding and use it as a transfer device between a high accuracy DC reference source and the AC to be measured. Such a circuit is shown in Fig. 1.

In order to measure the AC voltage "X," we use a transfer standard instrument to interpolate between the DC reference standard and the AC voltage. The transfer instrument is first switched to position B and a reading obtained.

SENSITIVE RESEARCH
INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

S
Symbol of Quality

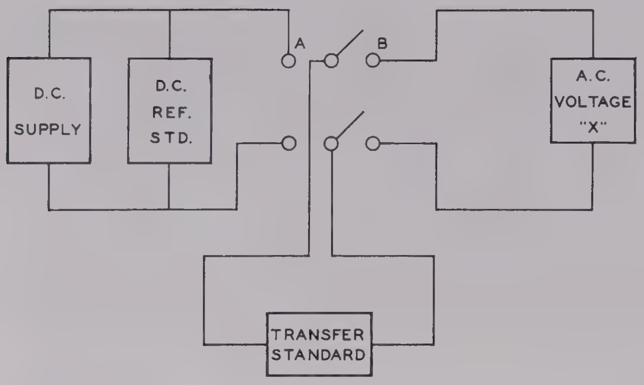


Fig. No. I

The switch is then transferred to the A position and the DC supply adjusted to bring the instrument to the exact same point. When the instrument indicates that the AC and DC voltages are identical, the DC reference standard is then read for the actual value of the DC voltage.

Assuming the transfer standard to be perfect, then the DC reference standard voltage is equal to the AC voltage "X." Taking a closer look at this we find several possibilities of error. We have, of course, the inherent error of loading of the transfer standard instrument in measuring the value "X."

This is common in all measurements, AC or DC, in which a power consuming device is required. Unfortunately, for high stability accurate measurements, we have no type of transfer standard which is not a power consuming device. This error, however, can be known to a high degree of certainty and allowance made for it.

We next have the possibility of error in the AC - DC transfer characteristics of the instrument itself. This error has to be investigated individually for the various types of transfer standards, which may be used.

There are three common types of transfer standards. The dynamometer instrument, the thermal instrument, and the electrostatic instrument. In the case of the dynamometer instrument, the AC - DC agreement runs into difficulty because of the inductance of the windings.

The dynamometer instrument can be made a satisfactory transfer instrument only for relatively low frequencies because of the effect of the inductance and distributed capacitance of its windings.

Let us look at the electrostatic instrument. Theoretically, the electrostatic instrument is a very satisfactory transfer device, up to quite high frequencies.

The theoretical limitations are those in which its mechanical dimensions become an appreciable fraction of a wave length. This limits the high frequency response of the instrument. It is also limited at those frequencies where its insulating materials become less than satisfactory. These frequency limitations, however, are far less severe than those of the dynamometer.

Unfortunately, the electrostatic does have one limitation to its use. Its basic sensitivity is poor and hence, it cannot be made for use at low voltages. The use of the electrostatic instrument as an accurate device is limited in general to voltages of several hundred volts or more in order to have a satisfactory torque to weight ratio for its moving element.

It is fairly obvious from the discussion so far, that we are bringing ourselves to the use of a thermal instrument. The thermal instrument is inherently an RMS responding instrument. The heater can be a relatively straight line, low inductance, low capacitance device and consume relatively little power by comparison to the dynamometer. Hence, it is as nearly an ideal transfer device as we can obtain.

The thermal transfer standard method is the most commonly used, except at power frequencies where the dynamometer is used because of its ruggedness.

The dynamometer instrument can be made satisfactory for transfer work to an accuracy of 1/10% or possibly somewhat better. One of the limitations of this instrument is that of its DC reversal characteristics.

When a dynamometer instrument is used on DC it is usually considered that its deflection bears no relation to the direction of flow of current. This is only approximately true and all commercially available instruments show at least some DC "reversal" effect in which the deflections are not identical when the DC voltage or current is reversed.

This usually necessitates Fig. I being modified to include a DC reversal switch for the DC supply and the DC reference standard. The assumption is then made that the average of the two reversed DC readings should be equal to the AC value. This is a satisfactory assumption, if the DC reversal effect is not too great.

Large DC reversals cannot be tolerated on instruments for this use, because the mean of the reversed DC readings presupposes that all of the factors involved are linear, an assumption which is not warranted with careful examination. The other two types of transfer instrument (the thermal and electrostatic) suffer to some lesser extent from this DC reversal effect.

In the case of the electrostatic, the effect becomes fairly pronounced on instruments at extremely high voltages due primarily to polarization effects in the insulators involved.

In the case of the thermal transfer unit, these reversal effects can be made very small by careful attention to the thermal junctions themselves, and in fact, thermal junctions are commercially available at this time from us with guaranteed DC reversal effects of not more than .01%.

With such tiny amounts of DC reversal, the assumption of linearity which allows the "mean" of DC values to equal the AC value introduces a completely negligible error.

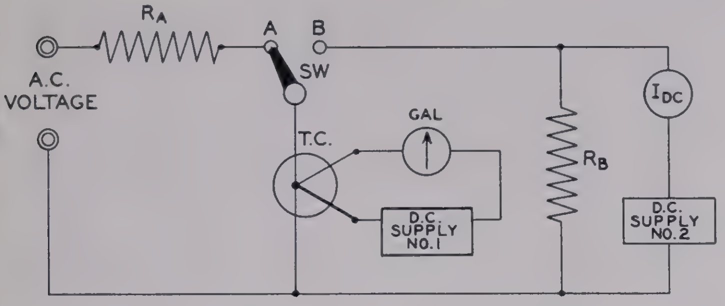
Actually, for a great majority of measurements a single DC value can be assumed and the reversal effect with its possible error of half the reversal or .005% completely disregarded.

In the use of a thermal transfer standard many circuits and arrangements may be used. However, the simplest and best is that devised by Francis L. Hermach of the Bureau of Standards, which has been adopted by SENSITIVE RESEARCH in their line of AC - DC test consoles.

The basic circuitry of the voltage transfer system is repeated in Fig. 2. Very complete discussions of this circuit have been given by both ourselves and other people and we will not elaborate to any great extent at this writing, except to quote the obvious advantages of such a circuit.

It is seen in Fig. 2 that when the transfer is made from the AC volt position to the DC substitution position, a resistor RB is shunted across the thermocouple in the DC sub position this resistor having exactly the same value as the series resistance RA used in the AC voltage position.

When the mathematics of this are followed through, it is seen that Vac or the applied AC voltage is equal to Idc X RA or RB, (they are identical). In other words, the thermocouple calibration constants and all other factors wash out of the picture entirely and the transfer is purely in terms of the measurement of a DC current and the value of a known resistance.



BASIC A.C.-D.C. VOLTAGE TRANSFER CIRCUIT

Fig. No. 2

The thermocouple is required to have only short term stability, (not change its value during the course of the transfer) and the method of measuring the thermocouple output be of sufficient sensitivity to detect very small differences.

SRIC is currently producing a new console, (the Model LTC-1). This is the second version of an elaborate test console in which RA and RB are a series of decade resistors which allow any value from .5 volt to 1100 volts to be set up as the test point.

The current measurement of Idc is made with the well known SENSITIVE RESEARCH INCREMETER instrument. With this circuitry we take advantage of the Hermach circuit which allows the DC substitution current to be of a single constant value regardless of the range of operation. Because of this single point operation the INCREMETER is used at a single reference point and can be calibrated directly in terms of percentage error of that point.

The Model LTC-1 contains several logical improvements over the preceding LTC. The first and most noticeable improvement is that of basic appearance, the instrument is now housed in an attractive grey aluminum case. That provides a really striking appearance. It has its own integral panel lighting.

While the appearance is a factor, the major reason for the metal case is to provide superior shielding. In some locations where there are extremely high level VHF signals there is a possibility of some signal pick-up by the internal wiring which the metal cabinet completely eliminates.

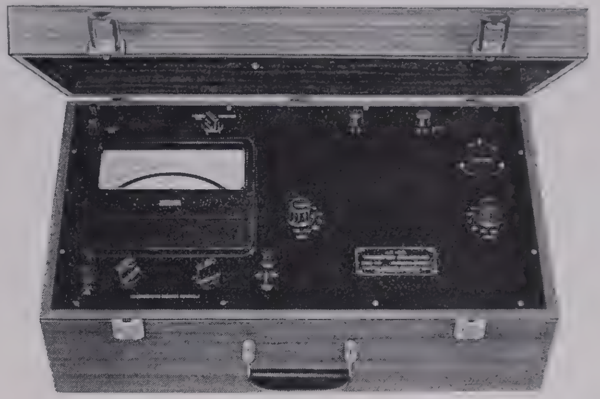
An improved galvanometer has been installed which allows more rapid readings and greater immunity to shock and vibration.

A slight re-arrangement of controls has been made which will allow for a somewhat smoother operation. All of the electrical circuitry involved is the same as the basic unit that has proven so satisfactory in field operation (our Model LTC).

The only basic electrical change in the entire instrument is a provision for potentiometric read out when required in place of the much more rapid incremeter error indicator on the front of the panel. In those cases where users require a very high degree of resolution for the inter-comparison of voltags or the detection of very small differences, a link on the back is provided where a potentiometer can be connected.

In this operation, the potentiometer will read exactly one volt for zero error and proportionate amounts high or low depending on the actual deviation from one volt. This allows for much greater resolution although the basic accuracy is not appreciably increased.

The LTC-1 successor to our Model LTC remains the widest range and most flexible test set available for relatively high speed calibration of an extremely wide range of AC and DC instruments.



MODEL FLH

AC/DC TRANSFER STANDARD

The Model LTC-1 being a commercial calibration console has of necessity some tolerances which are unavoidable in making such an instrument. The internal reference supply, the accuracy of adjustment of a large number of decade resistors and factors of this general nature give an overall accuracy conservatively rated at .05%.

A logical question is "how much farther is it possible to go?" In most standards work higher accuracy means the simplest most fundamental approach to the measurement, allowing the fewest steps between your standard and the instrument being measured.

This, of course, brings us back to Fig. 1. If, in Fig. 1, our reference DC standard is composed of the highest accuracy potentiometer we can obtain, the highest accuracy volt box and the highest accuracy saturated standard cell reference, we have then the best obtainable DC voltage standard. If to this we add an AC - DC transfer standard with the best available AC - DC differences, we will then be able to transfer our AC voltage "X" to our DC standards with a minimum of operations and hence, a minimum of inaccuracies.

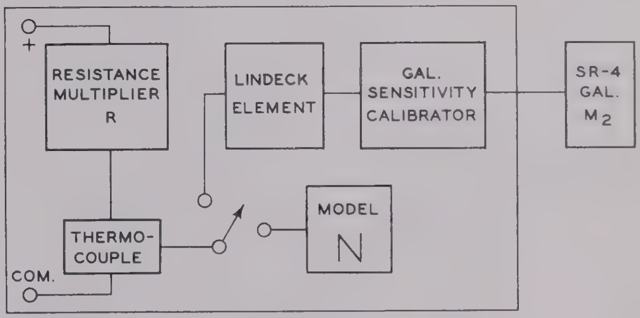


Fig. No 3

Such a transfer standard is our newly designed Model FLH. This is a high accuracy AC - DC difference test instrument or transfer standard. Fig. 3 shows the basic elements. With the switch thrown to the position connecting the indicating instrument, it creates a simple thermocouple type voltmeter. It is simple in that the circuitry is identical with that of our thermocouple voltmeters.

However, in this particular instrument the resistance multipliers have been designed purely on a basis of frequency response without the usual compromises to long term stability. The resistors and the range switch have frequency response well up into the megacycle range. Hence, to frequencies in the order of 30 kilocycles, the error due to AC - DC difference will be COMPLETELY NEGLIGIBLE.

The thermocouple used is housed in a position where it cannot change temperature rapidly and hence, the short term stability is excellent. All this means that the thermal element and the indicator instrument constitue an AC - DC transfer unit in which the actual AC to DC errors will be very small and the accuracy with which in AC measurement may be transferred to DC or vice-versa, is limited only by the ability to read the pointer of the instrument. To cure this deficiency we can switch to the Lindeck position.

In this position a very high resolution Lindeck element is used to provide a millivolt output which is made EQUAL and OPPOSITE to the output of the thermocouple. Ability to read this output is limited entirely to the sensitivity of the galvanometer to detect differences between the Lindeck element and the thermocouple output.

This sensitivity with our Model SR4 galvanometer normally furnished with the instrument is ample to show differences in the order of .002% or .003%. This difference shows up as a galvanometer deflection when the instrument is first zeroed in the DC position and then thrown to the AC position or vice versa. To calibrate this galvanometer deflection and make its value known in terms of actual percentage difference, two special calibration keys are provided on the Model FLH, one of which gives a deliberate downward shift in the output of .1% and the other a deliberate downward shift of .01%.

Pressing these keys provide immediate calibration of the instrument at the actual time of use. This unit, the Model FLH is to be available only with a National of Bureau's standard as to the actual AC - DC errors. The certificate values provided by NBS will allow an overall AC - DC difference accuracy of .01% or better.

The total errors in an AC voltage measurement then become something in this order of magnitude. For a SRIC Commander Type 9144 Potentiometer, .001%, another .001% for SRIC Commander 9700, or 9700A Volt Box and a third, .001% for a 9152 Constant Temperature Standard Cell Enclosure. This then is a total possible DC error of .003%, a value which in all probability would be markedly better in normal operation and to this would then be added the .01% of the Model FLH. The sum total would then reach the very satisfactory figure of .013% maximum possible error of the AC measurement. This is about the best that it is possible to do with actual certificated values on all of the instruments.

In actual practice accuracies of 2 to 3 times this will probably be obtained, but do not become legally provable. This, as anyone familiar with the techniques involved will realize, will be a somewhat slow, laborious method of meauring AC voltages. But it DOES produce the highest possible accuracies and it is actually the method used for the certification and calibration of the Model LTC-1 console.

The above Model FLH description has been based on voltage measurements which have provided the greatest difficulty in this range of accurate standards. An exact corollary for everything that has been stated can be made in terms of current. A simple multirange current version of the Model FLH voltage transfer standard will be available soon from SRIC.

In the meantime, the same basic system can be used, using individual thermocouples as current transfer devices with external Lindeck elements and galvanometers as detection devices. All our readers will be notified as soon as the commercial current version of the instrument has completed its test requirements and is ready for market. In the opening paragraph of this bulletin we used the term derivation of AC standards and measurements. As can be plainly seen from the lengthy dissertation between that paragraph and this, there are no AC standards. There are only means of transferring AC measurements to DC standards with their inherent accuracy and long term stability.

AC/DC CALIBRATION CONSOLE

MODEL LTC-1

ACCURACY:	± .05% of reading
AC/DC RANGES:	2 ma - 11.10 amperes in steps of 1 ma; .5 v - 1110 v in steps of .1 v
DC RANGES:	1 ma - 11.10 amperes in steps of 1 ma; .5 v - 1110 v in steps of .1 v
SENSITIVITY:	AC/DC, 100 ohms per volt; DC, 1000 ohms per volt All current ranges have a 2 v potential drop.
FREQUENCY RANGE:	.5 - 99 volts, DC - 25,000 cycles; 100 - 199 volts, DC - 20,000 cycles; 200 - 399 volts, DC - 12,500 cycle; 400 - 1110 volt, DC - 2,500 cycles; .002 - .499 ampere, DC - 20,000 cycles .500 - 1.99 amperes, DC - 10 kc; 2.00 - 11.10 amperes, DC - 5 kc. Lowest practical frequency for full accuracy is 10 cps.
READOUT:	Directly in "% Error" (+5%–0–5%) or in actual values.
POWER REQUIRED: (Not Supplied)	115 v 60 cycle source; two 6 volt storage batteries for DC current; and a regulated 1000 v DC power supply.
	Model LT-PS-1 power supply is available on separate order. It is an AC source capable of supplying up to 1000 volts or 10 amperes (50 va total), over a variable frequency range (20 cps - 20 kc), with low distortion (.1% - .25% max.) and high short term amplitude stability (± .01%).
SIZE:	36" left to right x 28" high x 20" deep.
WEIGHT:	125 lbs.
SHIPPING WEIGHT:	175 lbs.
PRICE:	$5,560.00
TERMS:	Net 30 days f.o.b., New Rochelle, New York

The calibration of all Sensitive Research instruments is directly traceable to the National Bureau of Standards in Washington, D. C. or Boulder, Colorado. Unless otherwise stated, warranty is for a period of one year.

AC/DC TRANSFER STANDARD

MODEL FLH

ACCURACY:	± .01%* of reading from 25 cps to 30 kc with NBS correction figures; ± .05% of reading or better without correction figures. NBS correction figures to ± .01%* accuracy to 50 kc may be procured by special arrangement. Correspondence required. *.01% Accuracy Certificates available from NBS approximately Nov. 1, 1961, presently calibrations at .02% accuracy.
RANGES:	1.5 - 3/7.5/15/30/75/150/300/750 v. (Ranges may be used from 50 - 150% of nominal value. Total measuring range is, therefore, 1.5 - 1125 volts.)
FREQUENCY RANGE:	DC 25 cps to 50 kc.
SENSITIVITY:	100 ohms per volt (approximately).
RESOLUTION:	.005%
GALVANOMETER: SENSITIVITY:	.002 μa /mm. Our Commander Type SR4 Galvanometer furnished will deflect approximately 2 mm for a ± .01% AC/DC difference. Our Type 5214 Photocell Amplifier and Type SR21 Galavanometer can be substituted to give a 100 mm deflection, minimum.
CASE:	Portable formica case with hinged cover.
SIZE:	21¼" x 13" x $6\frac{9}{16}$"
WEIGHT:	25 lbs.
SHIPPING WEIGHT:	45 lbs.
PRICE:	$1,685.00 (Includes *NBS Certificate and Type SR4 Galvanometer). If 5214 Amplifier and SR21 Galvanometer are desired, price is then $2,395.00.
TERMS:	Net 30 days f.o.b., NBS, Washington, D. C.

The Model FLH is guaranteed to maintain the stability of its frequency response indefinitely provided it is not physically or electrically abused. All parts and labor are warranted for a period of one year.

†See "COMMANDER" Catalog "A Brochure of Electrical Measuring Standards." Pg. 1 (Type 9144), Pg. 4 (Type 4305), PPg. 5 (Type 9700 & 9152), Pg. 6 (Types 5214 & SR21), a copy of which is yours for the asking.

Electrical MEASUREMENTS

VOLUME 28 MARCH, 1960 NUMBER 3

THE CONSOLE CONCEPT

LABORATORY
STANDARDIZING
TEST CONSOLE

MODEL **LTC**

D.C.—A.C./D.C.
LABORATORY STANDARDIZING TEST CONSOLE
D.C. CURRENT
A.C. CURRENT
A.C. VOLTS
D.C. VOLTS

ACCURACY

ALL RANGES

.05% of Actual Readings

**SENSITIVE RESEARCH
INSTRUMENT CORPORATION**

Symbol of Quality

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

...KNOW YOUR STANDARDS...

The rapidly expanding demand for high accuracy calibrations has made the design of some such equipment as the new SENSITIVE RESEARCH CALIBRATION CONSOLE a foregone conclusion. Historically speaking, whenever a country has needed a leader, a leader has emerged.

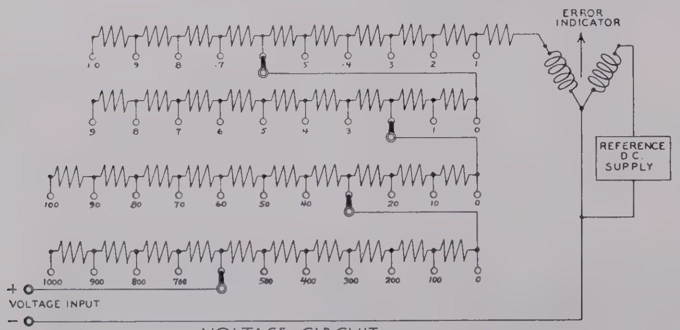
In science, when the need for some specific knowledge has been imperative, someone has found a way to get that knowledge. Commercially, whenever a real demand builds up in any field, some supplier comes forward to meet that demand.

The extreme need for high accuracy calibrations by both the military and civilian industry has rapidly outgrown the older laboratory approach to such measurements. The need is for simple DIRECT METHODS of calibration that combine the high accuracies of laboratory practices with the smooth, fast operation of production type measuring equipment. This need is very well met by the SENSITIVE RESEARCH CALIBRATION CONSOLES. These units bring into a single integrated unit the high accuracy shunts, volt multipliers, transfer systems, standards, and associated controls for switching the necessary circuits.

All of our Calibration Consoles have Walnut Formica cases with bakelite panels. They share a uniformity of appearance and each covers a specific range of needed calibrations. All the consoles have the range and set-up controls, together with read-out instruments, on a vertical front panel. The operating controls are on a conveniently sloped front panel for optimum ease of operation. This control panel extends slightly to the front and forms a shade for fluorescent tube lighting which gives an exceptionally pleasing, glare-free lighting of the instruments to be calibrated.

DC CIRCUITS

The circuit in Fig. 1 is typical of direct DC calibration circuits. In this particular arrangement the error indicator is the differential indicating instrument of the newly introduced SRIC INCREMETER. The differential instrument gives extremely high accuracy comparisons to a stabilized DC reference source which has a stability of .005%. This basic system is readily capable of individual point accuracies of .01%. It will be seen that the series voltage multipliers are set up in increments of .1 volt in decade steps. This eliminates the old bugaboo of "percentage of full scale" accuracies which occur with the usual 1 - 2 - 5 - 10 or the 1.5 - 3 - 7.5 - 15 ranges of voltage. This decade system is used in many of the SRIC consoles and provides an accuracy of .05% of reading.

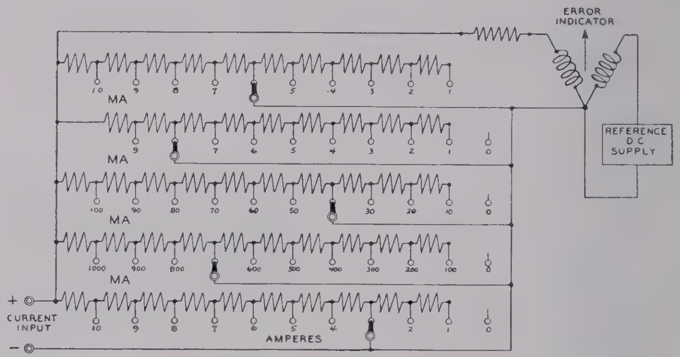


VOLTAGE CIRCUIT
OF D.C. CALIBRATOR SET

Fig. #1

Fig. 2 shows a similar sort of decade set-up which can be used for current measurements. The same INCREMETER type of high accuracy comparison instrument is used and the same sort of accuracies as achieved on voltage can be obtained. (.05% of reading.)

The using of decade multipliers in each case allows the actual value at which a calibration is desired to be set and hence the error indicator is always supplied with an identical signal when the input value is exactly equal to that set up with the decades. This gives a marked advantage in allowing us to calibrate the error indicator directly in percent error and have it read this value regardless of the setting in use.



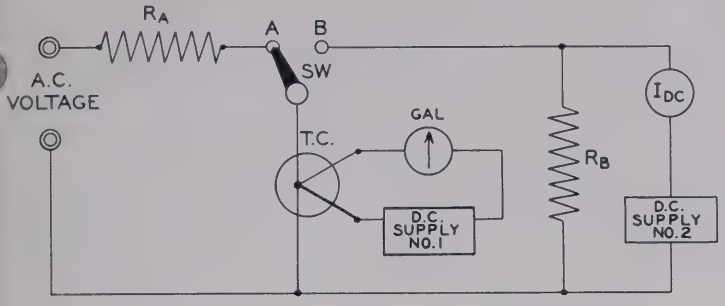
CURRENT CIRCUIT
OF D.C. CALIBRATION TEST SET

Fig. #2

AC CIRCUITS

AC measurements in all of the SENSITIVE RESEARCH STANDARDIZING CONSOLES are made by using a thermal transfer mechanism and transferring the measurements directly to its DC standards. The accuracy of the AC - DC transfer characteristics of selected thermocouples has been shown to be in the order of .01% in tests conducted by SENSITIVE RESEARCH INSTRUMENT CORPORATION over past years. The basic accuracy of such transfer measurements has been confirmed in extensive tests made at the NATIONAL BUREAU OF STANDARDS in Washington, D. C.

In the normal use of a thermocouple for AC - DC transfer measurements the resistance of the thermocouple heater, which is not an extremely stable characteristic, would enter into the calibration procedure. This heater resistance changes with operating temperature in normal operation, and also is subject to change with relatively small overloads. Dr. F. L. Hermach of the NATIONAL BUREAU OF STANDARDS has shown that a circuit (as shown in Fig. 3) will eliminate the effect of the thermocouple heater resistance in an AC - DC transfer element. If an AC voltage is impressed across R_a and the thermocouple heater by placing the switch in position "A", current will flow through the heater and produce a DC junction output voltage. DC supply No. 1 can be adjusted to give a stable output EXACTLY EQUAL and opposite to the couple output. At this point the galvanometer will indicate zero.



BASIC A.C.-D.C. VOLTAGE TRANSFER CIRCUIT Fig. #3

If we now change the switch (SW) to the "B" position and adjust DC supply #2 until the galvanometer returns to zero, we know that the thermocouple output is again the same as when the switch was in position "A" and hence the heater current is now identical to that which was produced by the original AC voltage. The original heater current is $I_{tc} = \frac{V_{ac}}{R_a + R_{tc}}$ The second heater current is $I_{tc} = \frac{I_{dc} R_{tc} R_b}{R_{tc} (R_{tc} + R_b)}$

Equating the two values of I_{tc} (the heater current) we have

$$\frac{V_{ac}}{R_a + R_{tc}} = \frac{I_{dc} R_{tc} R_b}{R_{tc} (R_{tc} + R_b)}$$

R_a & R_b = Calibrated resistance
R_{tc} = Thermocouple heater resistance
I_{tc} = Thermocouple heater current
V_{ac} = AC voltage

If now $R_a = R_b$ the equation reduces to $V_{ac} = I_{dc} R_b$, which shows that the thermocouple resistance drops out of the picture when we use a second shunt resistance across the thermocouple in position "B," which is equal to R_a.

In the actual operation, the resistance R_a is switched into the position of R_b for the DC substitution checking. This eliminates any variation between separate resistors by using the same identical units. R_a is actually a whole series of decade resistors to provide the various ranges required for calibration purposes.

The operation of this comparison circuit for AC - DC transfer is dependent on the short term stability of the thermocouple, the AC - DC errors of the thermocouple, the short term stability of the two DC supplies, and the absolute accuracy of the resistance decades. By very careful calibration of the complete console, all of these factors are carefully controlled, and the total accumulation of possible errors is held to better than .05% of value.

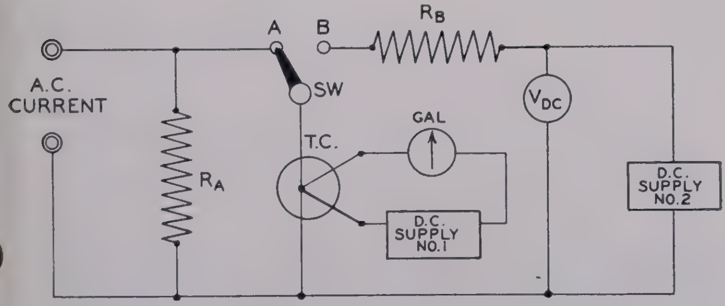


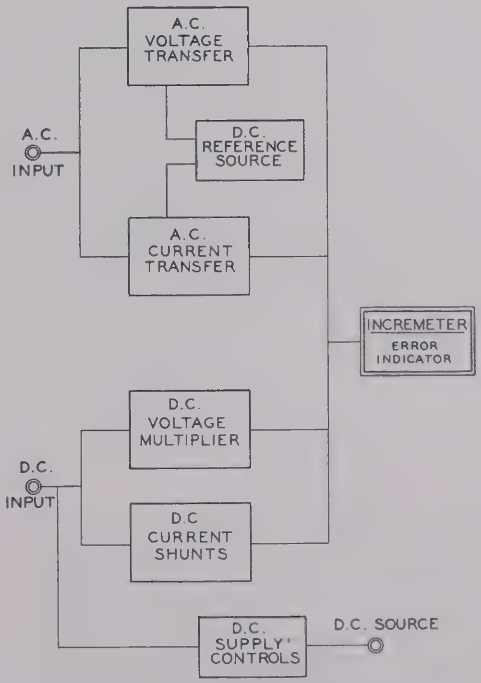
Fig. #4 BASIC A.C.-D.C. CURRENT TRANSFER CIRCUIT

For AC currents, a very similar circuit is used to eliminate the resistance of the thermocouple from the calibration accuracy. The circuit of this is shown in Fig. 4. The AC current is put through a shunt "R_a" and a thermocouple is connected directly across the shunt when the switch is in the "A" position. Similar to the operation for AC volts, the thermocouple output is balanced to zero by means of a stable DC supply #1. The thermocouple is then switched to the "B" position and a DC voltage applied through a compensating resistance "R_b" to produce the same thermocouple output as evidenced by the return of the galvanometer to zero. If R_a and R_b are equal, an analysis similar to that done for the AC voltage will show that $I_{ac} = \frac{V_{dc}}{R_a}$ and V_{dc} can be interpreted directly in terms of the AC input current. All the same factors apply as previously mentioned for the AC voltage transfer, and accuracies of .05% are readily obtainable.

The shunt is actually a series of decade resistances to cover the ranges required for calibration purposes. The shunts of a higher current value are made in a four terminal configuration to eliminate possible errors due to switching connections.

GENERAL

The basic calibration methods are the same in the entire line of SRIC consoles. The voltage or current is passed into either a multiplier or shunt of known high accuracy and referenced to either a standard cell or an electrical equivalent in the case of DC and in the case of AC a transfer system is interposed between the shunt or multipliers and the standard.



BLOCK DIAGRAM OF THE A.C.-D.C. LABORATORY STANDARD TEST CONSOLE

Model LTC

...MEASUREMENT IS THE BASIS OF PROGRESS...

The Model LTC utilizes the decade system for both current and voltage and hence gives an accuracy of .05% of reading as contrasted to the usual .05% of full scale accuracy. A Hermach transfer system is used for AC measurements. For the DC side of this console, the necessary controls for adjusting current and voltage are included in the console. The power supplies for the instrument being calibrated are not included with the console.

The Model LTA uses the usual steps of approximately two to one for both the voltage and current measurements. The resistance shunts and multipliers are used directly with an external potentiometer for DC measurements and transferred by means of a Hermach type thermal transfer for AC measurement. An extremely wide range of currents and voltages is covered.

ACCESSORY CURRENT TRANSFORMER

To extend range of current measurement of any of consoles listed.

Ranges — 2/5/10/20/50/100/200/250/500/1000 Amperes.

Accuracy .05% at 40% to 100% of rated current at frequencies from 60 to 1000 cycles. The error will not exceed .1% for above conditions to 2000 cycles nor will it exceed .1% up to 200% rated current at 60 to 400 cycles. Currents to 100 amperes, use wound primaries; for currents above 100 amperes, conductors are inserted though the transformer. Inserted primary insulation for 500 volt circuits is provided.

Code TRANSOLE List Price $750.00

LABORATORY STANDARDIZING TEST CONSOLES

Accuracy .05% of actual readings! MODEL **LTC** *(See front page picture)* 32¾" wide x 29" high x 23" deep 135 lbs.

SPECIFICATIONS

DC CURRENT	.001 ampere (1 ma.) to 11.10 amperes (2 volt drop, all settings)
DC VOLTS	.5 volt to 1111 volts (in increments of .1 volt) 1000 ohms per volt
AC CURRENT	.002 ampere (2 ma.) to 11.10 amperes (2 volt drop, all settings)
AC VOLTS	.5 volt to 1111 volts (in increments of .1 volt) 100 ohms per volt
FREQUENCY RANGE	.5 - 99 volts, DC - 25,000 cycles; 100 - 199 volts, DC - 20,000 cycles; 200 - 399 volts, DC - 12,500 cycles; 400 - 1110 volts, DC - 2,500 cycles .002 - .499 ampere, DC - 20,000 cycles; .500 - 1.99 amperes, DC - 10 kc; 2.00 - 11.10 amperes, DC - 5 kc.

POWER REQUIRED 115 volt 60 cycles source, 2 - 6 volt storage batteries and a regulated DC supply of 1000 volts capable of furnishing 10 ma. plus current drain of instrument under test. (A 500 volt supply can also be used if desired. This limits testing to the 0 - 500 volt ranges.) An AC supply capable of delivering 1000 volts and 11 amperes, not simultaneously, at the frequencies for which operation is required.

Complete WITHOUT batteries
or power supplies
PRICE $5560.00
Instructions included

MODEL **LTCA**

ALTERNATING CURRENT

Accuracy .05% of actual reading.

Model LTCA
27" wide x 28" high x 24" deep 120 lbs.

A demand for a wide range AC console of the general type of our LTC from laboratories with limited budgets has led to the offering of our model LTCA. This console is the AC PORTION of the model LTC and has all the features associated with that instrument except it does NOT have the extra decade shunts and resistors for the direct measurement of DC voltages and currents. DC measurements CAN still be made by means of the thermocouple transfer system which works equally well DC to DC as it will for AC to DC. The built-in controls for DC currents and voltages are NOT included as it is intended for operation with the users existing equipment.

This instrument has all the accuracy of the Model LTC console, lacking only in the speed of DC measurements.

SPECIFICATIONS

CURRENT	.002 ampere (2 ma.) to 11.10 ampere (2 volt drop, all settings)
VOLTS	.5 volt to 1110 volts in increments of .1 volt) 100 ohms per volt
FREQUENCY RANGE	.5 - 99 volts, DC - 25,000 cycles; 100 - 199 volts, DC - 20,000 cycles; 200 - 399 volts, DC - 12,500 cycles; 400 - 1110 volts, DC - 2500 cycles .002 - .499 amps, DC - 20,000 cycles; .500 - 1.99 amps, DC - 10 kc; 2.00 - 11.10 amps, DC - 5 kc

Complete WITHOUT batteries
or power supplies
Price $4550.00
Instructions included

POWER REQUIRED 115 volts, 60 cycle source and an AC supply, 0 - 1000 volts and 0 - 11 amperes (not simultaneously) at the frequencies for which operation is required.

MODEL **LTA**

Accuracy .05% of any range below.

Model LTA
27" wide x 28" high x 24" deep 120 lbs.

These ranges will all provide an E.M.F. of 1.5 volts to be measured by the potentiometer. The lowest practical reading on DC volts is 15 millivolts, on DC current .15 ma., on AC, due to certain thermocouple characteristics, lowest AC current is .75 ma. (.75 volt on potentiometer) and .15 volt (.75 volt on potentiometer).

SPECIFICATIONS

DC CURRENT	0 - 1.5/7.5/15/30/75/150/300/750 ma. & 1.5/3/7.5/15 amperes
DC VOLTS	0 - 1.5/3/7.5/15/30/75/150/300/750/1500 volts
AC CURRENT	1.5/3/7.5/15/30/75/150/300/750 ma. & 1.5/3/7.5/15 amperes
AC VOLTS	†.3/.75/1.5/3/7.5/15/30/75/150/300/750/1500 volts

Voltage ranges:	1.5 - 300 volts (up to 25 kc)
	750 volts (up to 10 kc)
	1500 volts (up to 7.5 kc)
Current ranges:	1.5 and 3 ma (up to 10 kc)
	7.5 ma to 1.5 amps (up to 25 kc)
	3 to 15 amps (up to 5 kc)

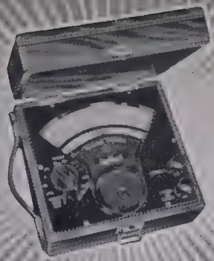
Accessories Required — 1.5 volt precision potentiometer, standard cell, sensitive galvanometer, with power supplies to deliver up to 15 amperes AC or DC and AC or DC to 1500 volts.

†.3 v. range only .1% accuracy.

Complete WITHOUT batteries
or power supplies
PRICE $2750.00
Instructions included

Printed in U.S.A.

Prices and specifications subject to change without notice.



Electrical MEASUREMENTS

VOLUME 28 MARCH, 1960 NUMBER 3

THE CONSOLE CONCEPT

LABORATORY
STANDARDIZING
TEST CONSOLE

MODEL **LTC**

ACCURACY

ALL RANGES

.05% of Actual Readings

**SENSITIVE RESEARCH
INSTRUMENT CORPORATION**

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

Symbol of Quality

...KNOW YOUR STANDARDS...

The rapidly expanding demand for high accuracy calibrations has made the design of some such equipment as the new SENSITIVE RESEARCH CALIBRATION CONSOLE a foregone conclusion. Historically speaking, whenever a country has needed a leader, a leader has emerged.

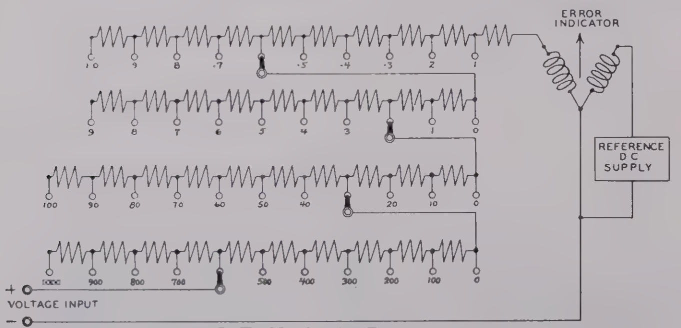
In science, when the need for some specific knowledge has been imperative, someone has found a way to get that knowledge. Commercially, whenever a real demand builds up in any field, some supplier comes forward to meet that demand.

The extreme need for high accuracy calibrations by both the military and civilian industry has rapidly outgrown the older laboratory approach to such measurements. The need is for simple DIRECT METHODS of calibration that combine the high accuracies of laboratory practices with the smooth, fast operation of production type measuring equipment. This need is very well met by the SENSITIVE RESEARCH CALIBRATION CONSOLES. These units bring into a single integrated unit the high accuracy shunts, volt multipliers, transfer systems, standards, and associated controls for switching the necessary circuits.

All of our Calibration Consoles have Walnut Formica cases with bakelite panels. They share a uniformity of appearance and each covers a specific range of needed calibrations. All the consoles have the range and set-up controls, together with read-out instruments, on a vertical front panel. The operating controls are on a conveniently sloped front panel for optimum ease of operation. This control panel extends slightly to the front and forms a shade for fluorescent tube lighting which gives an exceptionally pleasing, glare-free lighting of the instruments to be calibrated.

DC CIRCUITS

The circuit in Fig. 1 is typical of direct DC calibration circuits. In this particular arrangement the error indicator is the differential indicating instrument of the newly introduced SRIC INCREMETER. The differential instrument gives extremely high accuracy comparisons to a stabilized DC reference source which has a stability of .005%. This basic system is readily capable of individual point accuracies of .01%. It will be seen that the series voltage multipliers are set up in increments of .1 volt in decade steps. This eliminates the old bugaboo of "percentage of full scale" accuracies which occur with the usual 1 - 2 - 5 - 10 or the 1.5 - 3 - 7.5 - 15 ranges of voltage. This decade system is used in many of the SRIC consoles and provides an accuracy of .05% of reading.

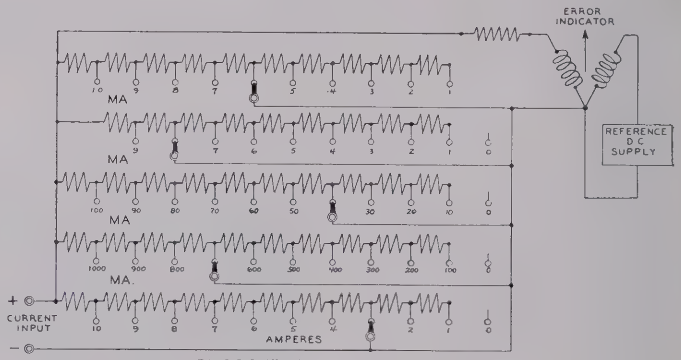


VOLTAGE CIRCUIT
OF D.C. CALIBRATOR SET

Fig. #1

Fig. 2 shows a similar sort of decade set-up which can be used for current measurements. The same INCREMETER type of high accuracy comparison instrument is used and the same sort of accuracies as achieved on voltage can be obtained. (.05% of reading.)

The using of decade multipliers in each case allows the actual value at which a calibration is desired to be set and hence the error indicator is always supplied with an identical signal when the input value is exactly equal to that set up with the decades. This gives a marked advantage in allowing us to calibrate the error indicator directly in percent error and have it read this value regardless of the setting in use.



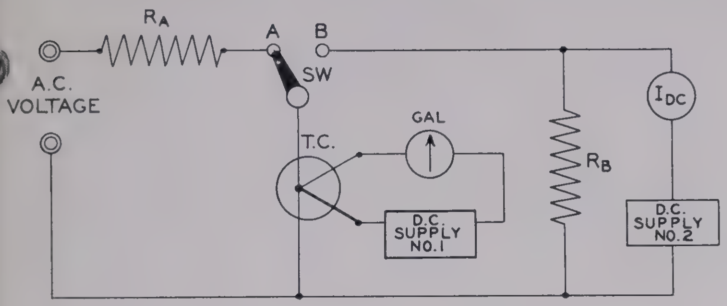
CURRENT CIRCUIT
OF D.C. CALIBRATION TEST SET

Fig. #2

AC CIRCUITS

AC measurements in all of the SENSITIVE RESEARCH STANDARDIZING CONSOLES are made by using a thermal transfer mechanism and transferring the measurements directly to its DC standards. The accuracy of the AC - DC transfer characteristics of selected thermocouples has been shown to be in the order of .01% in tests conducted by SENSITIVE RESEARCH INSTRUMENT CORPORATION over past years. The basic accuracy of such transfer measurements has been confirmed in extensive tests made at the NATIONAL BUREAU OF STANDARDS in Washington, D. C.

In the normal use of a thermocouple for AC - DC transfer measurements the resistance of the thermocouple heater, which is not an extremely stable characteristic, would enter into the calibration procedure. This heater resistance changes with operating temperature in normal operation, and also is subject to change with relatively small overloads. Dr. F. L. Hermach of the NATIONAL BUREAU OF STANDARDS has shown that a circuit (as shown in Fig. 3) will eliminate the effect of the thermocouple heater resistance in an AC - DC transfer element. If an AC voltage is impressed across R_a and the thermocouple heater by placing the switch in position "A", current will flow through the heater and produce a DC junction output voltage. DC supply No. 1 can be adjusted to give a stable output EXACTLY EQUAL and opposite to the couple output. At this point the galvanometer will indicate zero.



BASIC A.C.-D.C. VOLTAGE TRANSFER CIRCUIT

Fig. #3

If we now change the switch (SW) to the "B" position and adjust DC supply #2 until the galvanometer returns to zero, we know that the thermocouple output is again the same as when the switch was in position "A" and hence the heater current is now identical to that which was produced by the original AC voltage. The original heater current is $I_{tc} = \frac{V_{ac}}{R_a + R_{tc}}$ The second heater current is $I_{tc} = \frac{I_{dc} R_{tc} R_b}{R_{tc}(R_{tc} + R_b)}$

Equating the two values of I_{tc} (the heater current) we have

$$\frac{V_{ac}}{R_a + R_{tc}} = \frac{I_{dc} R_{tc} R_b}{R_{tc}(R_{tc} + R_b)}$$

R_a & R_b = Calibrated resistance
R_{tc} = Thermocouple heater resistance
I_{tc} = Thermocouple heater current
V_{ac} = AC voltage

If now $R_a = R_b$ the equation reduces to $V_{ac} = I_{dc} R_b$, which shows that the thermocouple resistance drops out of the picture when we use a second shunt resistance across the thermocouple in position "B," which is equal to R_a.

In the actual operation, the resistance R_a is switched into the position of R_b for the DC substitution checking. This eliminates any variation between separate resistors by using the same identical units. R_a is actually a whole series of decade resistors to provide the various ranges required for calibration purposes.

The operation of this comparison circuit for AC - DC transfer is dependent on the short term stability of the thermocouple, the AC - DC errors of the thermocouple, the short term stability of the two DC supplies, and the absolute accuracy of the resistance decades. By very careful calibration of the complete console, all of these factors are carefully controlled, and the total accumulation of possible errors is held to better than .05% of value.

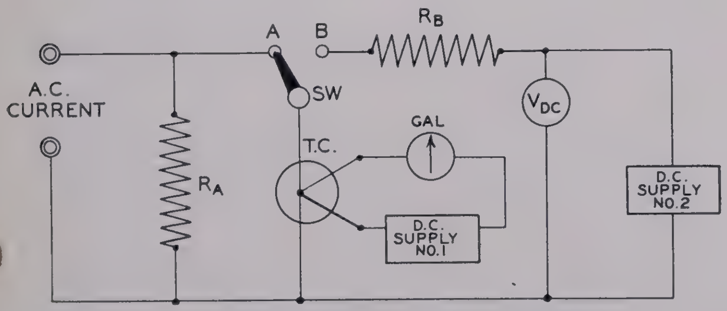


Fig. #4

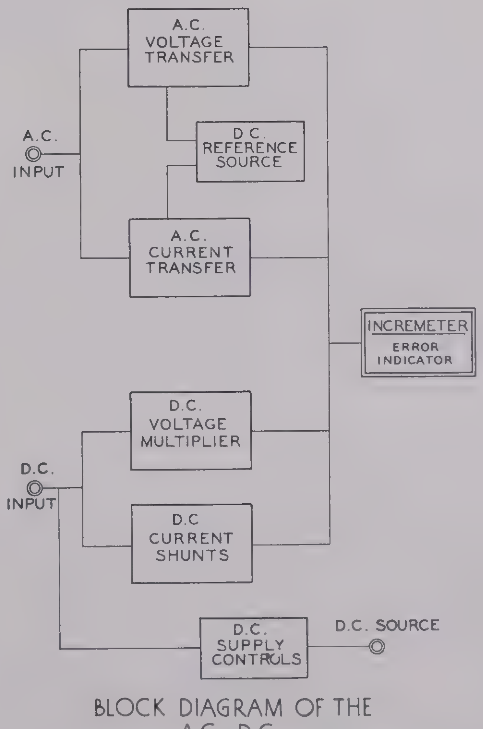
BASIC A.C.-D.C. CURRENT TRANSFER CIRCUIT

For AC currents, a very similar circuit is used to eliminate the resistance of the thermocouple from the calibration accuracy. The circuit of this is shown in Fig. 4. The AC current is put through a shunt "R_a" and a thermocouple is connected directly across the shunt when the switch is in the "A" position. Similar to the operation for AC volts, the thermocouple output is balanced to zero by means of a stable DC supply #1. The thermocouple is then switched to the "B" position and a DC voltage applied through a compensating resistance "R_b" to produce the same thermocouple output as evidenced by the return of the galvanometer to zero. If R_a and R_b are equal, an analysis similar to that done for the AC voltage will show that $I_{ac} = \frac{V_{dc}}{R_a}$ and V_{dc} can be interpreted directly in terms of the AC input current. All the same factors apply as previously mentioned for the AC voltage transfer, and accuracies of .05% are readily obtainable.

The shunt is actually a series of decade resistances to cover the ranges required for calibration purposes. The shunts of a higher current value are made in a four terminal configuration to eliminate possible errors due to switching connections.

GENERAL

The basic calibration methods are the same in the entire line of SRIC consoles. The voltage or current is passed into either a multiplier or shunt of known high accuracy and referenced to either a standard cell or an electrical equivalent in the case of DC and in the case of AC a transfer system is interposed between the shunt or multipliers and the standard.



BLOCK DIAGRAM OF THE A.C.-D.C. LABORATORY STANDARD TEST CONSOLE

Model LTC

...MEASUREMENT IS THE BASIS OF PROGRESS...

The Model LTC utilizes the decade system for both current and voltage and hence gives an accuracy of .05% of reading as contrasted to the usual .05% of full scale accuracy. A Hermach transfer system is used for AC measurements. For the DC side of this console, the necessary controls for adjusting current and voltage are included in the console. The power supplies for the instrument being calibrated are not included with the console.

The Model LTA uses the usual steps of approximately two to one for both the voltage and current measurements. The resistance shunts and multipliers are used directly with an external potentiometer for DC measurements and transferred by means of a Hermach type thermal transfer for AC measurement. An extremely wide range of currents and voltages is covered.

ACCESSORY CURRENT TRANSFORMER

To extend range of current measurement of any of consoles listed.

Ranges — 2/5/10/20/50/100/200/250/500/1000 Amperes.

Accuracy .05% at 40% to 100% of rated current at frequencies from 60 to 1000 cycles. The error will not exceed .1% for above conditions to 2000 cycles nor will it exceed .1% up to 200% rated current at 60 to 400 cycles. Currents to 100 amperes, use wound primaries; for currents above 100 amperes, conductors are inserted though the transformer. Inserted primary insulation for 500 volt circuits is provided.

Code TRANSOLE List Price $750.00

LABORATORY STANDARDIZING TEST CONSOLES

Accuracy .05% of actual readings! MODEL **LTC** *(See front page picture)* 32¾" wide x 29" high x 23" deep 135 lbs.

SPECIFICATIONS

DC CURRENT	.001 ampere (1 ma.) to 11.10 amperes (2 volt drop, all settings)
DC VOLTS	.5 volt to 1111 volts (in increments of .1 volt) 1000 ohms per volt
AC CURRENT	.002 ampere (2 ma.) to 11.10 amperes (2 volt drop, all settings)
AC VOLTS	.5 volt to 1111 volts (in increments of .1 volt) 100 ohms per volt
FREQUENCY RANGE	.5 - 99 volts, DC - 25,000 cycles; 100 - 199 volts, DC - 20,000 cycles; 200 - 399 volts, DC - 12,500 cycles; 400 - 1110 volts, DC - 2,500 cycles .002 - .499 ampere, DC - 20,000 cycles; .500 - 1.99 amperes, DC - 10 kc; 2.00 - 11.10 amperes, DC - 5 kc.

POWER REQUIRED 115 volt 60 cycles source, 2 - 6 volt storage batteries and a regulated DC supply of 1000 volts capable of furnishing 10 ma. plus current drain of instrument under test. (A 500 volt supply can also be used if desired. This limits testing to the 0 - 500 volt ranges.) An AC supply capable of delivering 1000 volts and 11 amperes, not simultaneously, at the frequencies for which operation is required.

Complete WITHOUT batteries
or power supplies
PRICE $5560.00
Instructions included

MODEL **LTCA**

ALTERNATING CURRENT

Accuracy .05% of actual reading.

Model LTCA
27" wide x 28" high x 24" deep 120 lbs.

A demand for a wide range AC console of the general type of our LTC from laboratories with limited budgets has led to the offering of our model LTCA. This console is the AC PORTION of the model LTC and has all the features associated with that instrument except it does NOT have the extra decade shunts and resistors for the direct measurement of DC voltages and currents. DC measurements CAN still be made by means of the thermocouple transfer system which works equally well DC to DC as it will for AC to DC. The built-in controls for DC currents and voltages are NOT included as it is intended for operation with the users existing equipment.

This instrument has all the accuracy of the Model LTC console, lacking only in the speed of DC measurements.

SPECIFICATIONS

CURRENT	.002 ampere (2 ma.) to 11.10 ampere (2 volt drop, all settings)
VOLTS	.5 volt to 1110 volts in increments of .1 volt) 100 ohms per volt
FREQUENCY RANGE	.5 - 99 volts, DC - 25,000 cycles; 100 - 199 volts, DC - 20,000 cycles; 200 - 399 volts, DC - 12,500 cycles; 400 - 1110 volts, DC - 2500 cycles .002 - .499 amps, DC - 20,000 cycles; .500 - 1.99 amps, DC - 10 kc; 2.00 - 11.10 amps, DC - 5 kc

Complete WITHOUT batteries
or power supplies
Price $4550.00
Instructions included

POWER REQUIRED 115 volts, 60 cycle source and an AC supply, 0 - 1000 volts and 0 - 11 amperes (not simultaneously) at the frequencies for which operation is required.

MODEL **LTA**

Accuracy .05% of any range below.

Model LTA
27" wide x 28" high x 24" deep 120 lbs.

These ranges will all provide an E.M.F. of 1.5 volts to be measured by the potentiometer. The lowest practical reading on DC volts is 15 millivolts, on DC current .15 ma., on AC, due to certain thermocouple characteristics, lowest AC current is .75 ma. (.75 volt on potentiometer) and .15 volt (.75 volt on potentiometer).

SPECIFICATIONS

DC CURRENT	0 - 1.5/7.5/15/30/75/150/300/750 ma. & 1.5/3/7.5/15 amperes
DC VOLTS	0 - 1.5/3/7.5/15/30/75/150/300/750/1500 volts
AC CURRENT	1.5/3/7.5/15/30/75/150/300/750 ma. & 1.5/3/7.5/15 amperes
AC VOLTS	†.3/.75/1.5/3/7.5/15/30/75/150/300/750/1500 volts

Voltage ranges:	1.5 - 300 volts (up to 25 kc)
	750 volts (up to 10 kc)
	1500 volts (up to 7.5 kc)
Current ranges:	1.5 and 3 ma (up to 10 kc)
	7.5 ma to 1.5 amps (up to 25 kc)
	3 to 15 amps (up to 5 kc)

Accessories Required — 1.5 volt precision potentiometer, standard cell, sensitive galvanometer, with power supplies to deliver up to 15 amperes AC or DC and AC or DC to 1500 volts.

†.3 v. range only .1% accuracy.

Complete WITHOUT batteries
or power supplies
PRICE $2750.00
Instructions included

Printed in U.S.A.

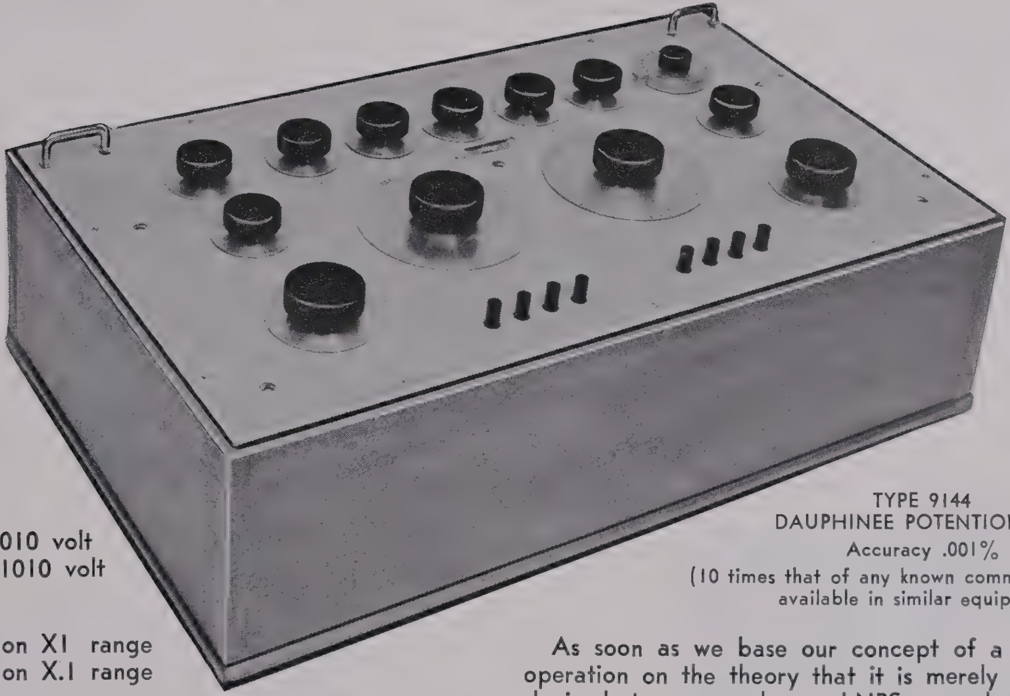
Prices and specifications subject to change without notice.

Electrical MEASUREMENTS

APR 2 1961

VOLUME 28 FEBRUARY, 1961 NUMBER 2

A SELF SUFFICIENT
ELECTRICAL STANDARDS PROGRAM



Ranges
X1 to 2.101010 volt
X.1 to .2101010 volt

Resolution
1 microvolt on X1 range
.1 microvolt on X.1 range

TYPE 9144
DAUPHINEE POTENTIOMETER
Accuracy .001%
(10 times that of any known commercial accuracy available in similar equipment)

ELECTRICAL STANDARDS DEPARTMENTS come in all sizes and shapes. They may be in one corner of a bench someplace in an out of the way section of the plant. They may occupy floors of carefully air-conditioned, humidified rooms, with much equipment and many people or, they may be somewhere between these two extremes. However, fundamentally, they all exist for exactly one purpose — that is to show the relationship between electrical measurements made in the plant and those made at the National Bureau of Standards in Washington, D. C. or Boulder, Colorado.

Absolute measurements represent many man months for a single determination of current or resistance and, hence, are impractical for any except such national standardizing institutions such as NBS.

As soon as we base our concept of a standardizing operation on the theory that it is merely a comparison device between ourselves and NBS, several questions arise. First, does our standards department become merely a repository of a group of duplicate measuring equipment similar to that used in the plant, with this equipment continually shuttling back and forth between ourselves and the Bureau? Or, do we set up only one or two fundamental standards from the Bureau and derive the balance of our measurements from these standards and, if we do this, what are the units which we use for NBS transfer?

There are many versions of the answers to these questions. If we operate on the first proposed scheme of "keep a duplicate of everything and send it to the Bureau," we soon find ourselves in trouble. Many of the pieces of gear which we would like to use in this fashion do not have sufficient long-term stability to justify such travelling to and from the Bureau.

SENSITIVE RESEARCH
INSTRUMENT CORPORATION
NEW ROCHELLE, N. Y.
ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927
Symbol of Quality

Also, if enough people adopt this sort of philosophy, the Bureau of Standards would soon be so overloaded that it would be impossible for them to keep up with the tremendous number of routine measurements.

In many fields the NBS is already reaching this situation and, of necessity, they must then cut back on the routine measurements, in order to conserve their personnel for the more important and technically rewarding fields of working on tomorrow's measurements rather than today's routine calibrations.

Suppose we take the opposite approach and ask ourselves the following question: "What is the absolute minimum of cross checking equipment we require in order to maintain satisfactory wide range standards in our own plant for long periods of time." This question starts us looking at the overall long-term stability of the various electrical standards.

We find first, that saturated standard cells maintained at a constant temperature, provide an excellent long-term stability device for the maintaining of standard voltages. The working standard of voltage for the United States is maintained by the National Bureau of Standards in the form of about 30 saturated standard cells, most of which are about 40 years old.

The assured drift rate of such a bank of saturated cells is such that yearly cross-checks by means of a portable standard with the Bureau of Standards in Washington or Boulder, would be ample to assure accuracies in the order of four or five parts per million. A look at unsaturated cells, however, shows that the great majority of these units have a steady drift which, unfortunately, may be either up or down and, hence, are not satisfactory for maintaining long-term stability although they are commonly used for interim measurements, plant standards, secondary working standards and things of this general class.

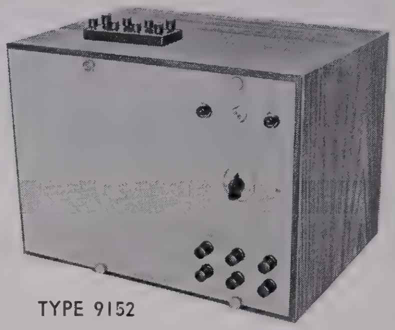
"Voltage Standard"

MODEL STV
Accuracy .01%

All types of standard cells are subject to damage from overload if they are abused when current is drawn from them in any appreciable amount. For this reason, many standards groups are changing to the Sensitive Research Model STV, standard voltage source, for secondary voltage standards instead of using unsaturated standard cells. The stability is comparable with such unsaturated cells and the fact that they are so immune to abuse, standing a short circuit indefinitely without damage, that they provide a more satisfactory reference. They will, of course, for utmost accuracy, require a regular check against a saturated bank for purposes of certification.

The inescapable conclusion then is that the Standards Department will require a bank of saturated standard cells in a constant temperature enclosure. The **COMMANDER*, type 9152, is an excellent example of such a device.

Having established our own voltage standard, we require either a current standard or a resistance standard in order to be able to accomplish all our measurements. Current is obviously a transient phenomenon and, hence, it is physically impossible to establish a current standard as such. However, when we look at resistance, we find that the four terminal NBS types of resistance as designed originally by Dr. Thomas of NBS, show excellent long-term stability and relative immunity to reasonable overloads and, hence, provide a very satisfactory basic standard. We find that yearly checks of such resistors are satisfactory to maintain accuracies in the general order of four or five parts per million.



Accommodates
Four
Standard
Cells

Temperature
variations held
within ± .01 C

TYPE 9152

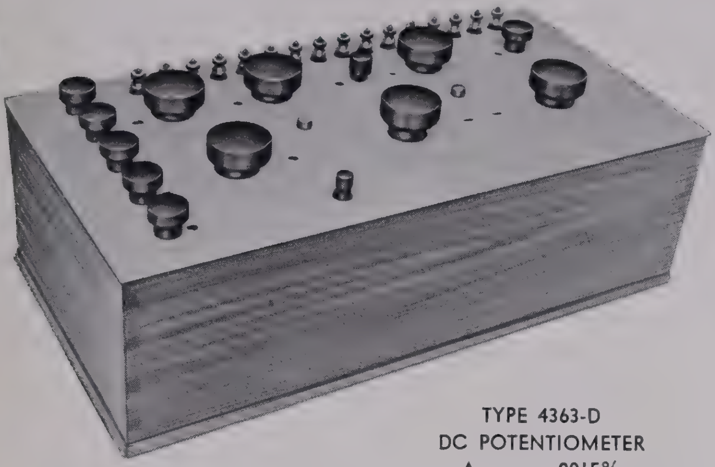
These four or five parts per million will probably not be obtained, or at least be completely assured, until one has a working history on the standard cells and resistances. In general, it is suggested that these instruments be certified by the Bureau of Standards at the time they go into service and at the end of six months, and then probably yearly thereafter will be ample to maintain this working accuracy.

Having established satisfactory basic standards for voltage and resistance and by combining the two, also standards of current, we find we need satisfactory devices for extending the ranges of operation. We need, for instance, to be able to measure voltages other than that of our standard cell bank, both higher and lower. Lower, of course, means a high accuracy potentiometer, which will cover the range from the general vicinity of standard cells, or a little above, on down through into the millivolt and, in some cases, microvolt range.

If we are to attempt to maintain comparisons, sufficiently valid to be reasonable for use with the standards just established, we require a potentiometric linearity at least comparable with the absolute values of resistance and voltage which we have set up. This means we need resolution of at least one part per million and we need absolute accuracy in terms of potentiometer linearity of possibly somewhat less than this.

Such equipment is represented by the *COMMANDER* 9144, the *COMMANDER* 4363-D and the *COMMANDER* 3589-S potentiometers. All of these units have accuracies in this range and are satisfactory for measurements from a few microvolts up to one or two volts (except in the case of the 3589-S which has a top voltage of .11111 volts) with resolution and basic linearity sufficient for use with these standards.

*All "COMMANDER" instruments are manufactured for "Sensitive Research" by Guildline Instruments, Limited in Canada.

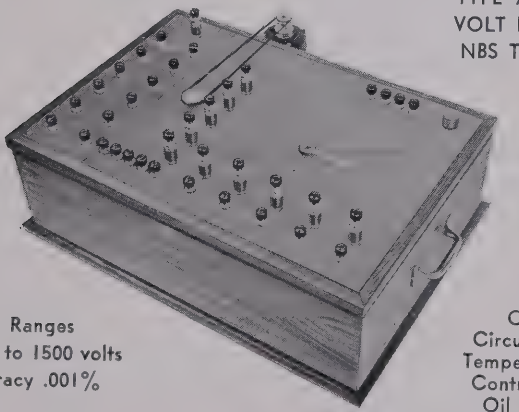


TYPE 4363-D
DC POTENTIOMETER
Accuracy .0015%

RANGES X1 to 1.901010 volts
X.1 to .1901010 volt
Resolution 1 microvolt on X1 Range
.1 microvolt on X.1 Range

To extend the voltage range upward, the National Bureau of Standards has designed a volt box, described in their research paper No. RP 1419, in which the various ranges are so selected that it is possible not only to have a highly accurate and stable box, but to cross-check the various sections and literally bootstrap one's self up to as high as 1500 volts, by means of only a stable voltage source and an accurate potentiometer.

Volt boxes of this type are inherently more stable and accurate than the ordinary volt box due to the large number of bobbins employed on the higher volt ranges, maintaining a constant watts-per-square centimeter for all the resistors involved. Also, these devices are provided with a guard circuit which eliminates the possibility of leakage causing an error at higher voltages.

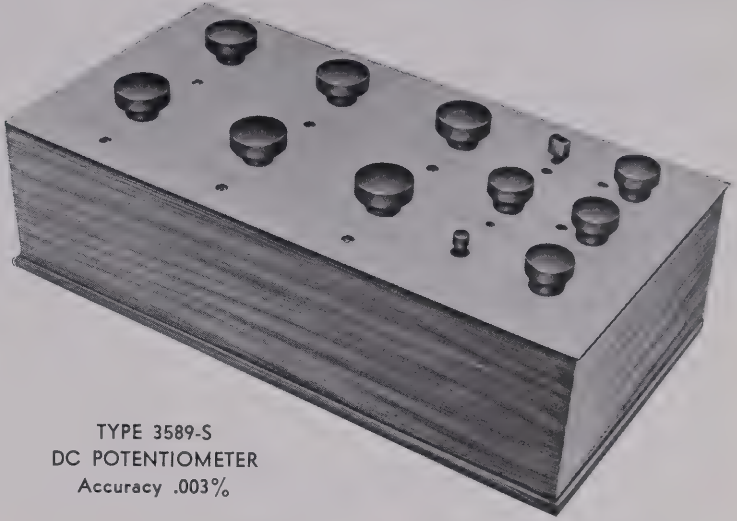


TYPE 9700
VOLT BOX
NBS Type

15 Ranges
.15 volt to 1500 volts
Accuracy .001%

Oil
Circulated
Temperature
Controlled
Oil Bath

The *COMMANDER* 9700 volt box and the *COMMANDER* 9700-A, reading to top voltages of 750 and 1500 volts respectively, are excellent examples of this type of volt box. Such volt boxes do not require Bureau certification in order to maintain working accuracies over long periods of time, because of the possibility of this self-check which is inherent in the design of the instrument. Hence, as far as voltages are concerned, a potentiometer of the types described will provide satisfactory extrapolation on down into the microvolt range from the standard cell voltage and the volt box will provide extrapolation up above this voltage to 1500 volts.



TYPE 3589-S
DC POTENTIOMETER
Accuracy .003%

RANGES X1 to .111110 volt
X.1 to .0111110 volt
Resolution 1 microvolt on X1 Range
.1 microvolt on X.1 Range

At this point, one additional factor immediately becomes pertinent. In extrapolating the voltage upward with the NBS type volt box, we have self-check provisions which can give us assured accuracies at the higher voltages. If we limit our choice of potentiometers to the *COMMANDER* type 9144, we have this self-same check provision built into the equipment allowing us to check the linearity of the main dials and standard cell circuits without recourse to any equipment other than another potentiometer with sufficient sensitivity to detect a microvolt and sufficient short-term stability to hold it during the course of a reading.

This second potentiometer does not have to have any accuracy or NBS checking of its own operation. The 9144 has built into its own circuitry all of the necessary switches and extra connections to provide complete external self-check procedures to assure the user of accuracy throughout its range without recourse to separate checks and, hence, any necessity for the potentiometer itself to go to the Bureau. To the best of our belief and knowledge, this 9144 is the only potentiometer of which this is completely true.

Now we reach the problem of extending our resistance ranges from possibly a single one ohm NBS standard which we had calibrated and certified at the Bureau. For this, one can use a Wenner Bridge or any one of several other devices to inter-compare resistors of similar values or resistors of nearby values.

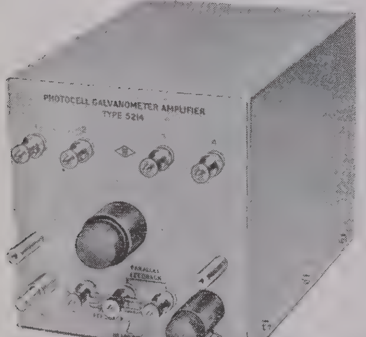
We can ALSO use the *COMMANDER* 9144 potentiometer as a ratio device for checking of standard resistors. A unique feature of this potentiometer is inclusion in the standard cell side of the potentiometer positions for one volt, one-half volt, two-tenths volt and one-tenth volt. If, then, one sets up a common current through a known resistor and an unknown resistor and applies the potential from the known resistor to the nominal one volt position of the standardizing circuit on the potentiometer and the drop across the unknown resistor is applied to the normal EMF positions of the potentiometer, a balancing of the pot by means of the EMF dials will immediately indicate the exact ratio between the two resistors. These EMF dials can be direct reading then in resistance, requiring only the proper placing of a decimal point. This is true even though the standard resistor may have known corrections.

There is included a special set of red figures on the standard cell dial which reads from zero to plus or minus 50 parts per million. When this dial is used for setting in the necessary corrections to the standard, the main dials become DIRECT READING in absolute resistance.

By this method which has a comparative accuracy in the order of one part per million, ranges of resistance of from twice the known standard resistance down to well below one-tenth of the standard resistance can readily be compared. By this method, it is relatively easy to extrapolate in steps of not more than ten to one, in either direction, from the basic one ohm NBS standard. By this method we now can have working standards with a practically infinite range of resistance, a wide range of voltage and we still have not exhausted the possibility of this universal piece of test equipment as the *COMMANDER* 9144 potentiometer.

In order to extend the accuracy of our saturated standard cell bank out into the plant, we would normally use other saturated cells for the highest accuracy and for somewhat lower accuracies either the SRIC Model STV, or unsaturated standard cells. We need a means of comparing these to our saturated bank.

For this use, the *COMMANDER* 9144 makes an excellent standard cell comparitor. The simplest method of using this is to connect four circuits to the EMF terminals of the 9144 potentiometer through a 9145 thermo free switch. Connect to one position terminals of the standard cell to be measured and to the other three positions, three of the cells in our standard cell bank. By switching to any one of the three standard cells in the bank, the EMF dials are set to its known value and the current in the potentiometer balanced without recourse to the standardizing circut of the potentiometer. For utmost accuracy, we then cross-check the two other cells of the saturated cell bank. Without restandardizing the operating current in the potentiometer, switch to the unknown cell to be certified, rebalancing by means of the EMF dials only, the value of the unknown cell is determined directly from the EMF readings. These readings are readily made to one microvolt directly from the dials.



Current Sensitivity
up to
350,000 mm
per microampere

TYPE 5214

PHOTO CELL
GALVANOMETER
AMPLIFIER

TYPE SR-21 GALVANOMETER
Sensitivity .002 microamperes per mm

If a *COMMANDER* 5214 galvanometer amplifier is used, preferably with its companion SR 21 secondary galvanometer, galvanometer sensitivity can be made sufficiently great that extrapolation between the one microvolt steps on the finest dial can readily be made to much better than a tenth of a microvolt. This resolution is very comparable with any other possible standard cell comparitor device and, of course, we have had to have only one single potentiometer to accomplish this.

It is obvious from the above descriptions that we consider the *COMMANDER* Model 9144 as the heart of a standards operation, because of its use both as a potentiometer, as a resistor comparitor, as a standard cell comparitor and because of its self-check features. For these applications where you require its use as only a potentiometer on a full-time basis, then one should very well consider the 4363-D which is very nearly its equal as a potentiometer. If one has full-time usage for a straight resistance comparitor, then one of the Wenner comparitor bridges is slightly faster and more convenient. If one has full-time use for a standard cell comparitor, some of the specialized standard cell comparitors on the market are a little bit faster and more convenient for this operation.

Unless the standards department has sufficient work to keep three separate instruments in full time use, the 9144 is the logical choice. The 9144 doing all three jobs, will keep the small plant standards investment at a minimum and still keep complete coverage available. Also, because of its wide-range facilities, it becomes an excellent second device for the extremely well-equipped department.

For instance, if one had all three of the equipments mentioned — the potentiometer, the comparitor bridge, the standard cell comparitor — in order to have spares, one would need three separate spares. The 9144 would provide alternate facilities for any one of the three when required. In other words, we are enthusiastic about the possibilities of this instrument.

The combination of a 9144 potentiometer, a 5214 galvanometer amplifier, and SR 21 galvanometer for use with the 5214, an SR 4 galvanometer for use in the standard cell circuit for uses requiring simultaneous main dial and standard dial balance and a 9145 thermo free switch for switching inputs to the potentiometer constitute the heart of a complete standards set-up. The user of such equipment can then be assured of measurements to the highest degree of accuracy obtainable today.

These instruments are described in detail in our brochure on ELECTRICAL MEASURING STANDARDS, a copy of which is yours for the asking. Our Model STV standard volt is described in our general instrument catalog.

Electrical MEASUREMENTS

APR 25 1961

VOLUME 28 FEBRUARY, 1961 NUMBER 2

A SELF SUFFICIENT
ELECTRICAL STANDARDS PROGRAM

Ranges
X1 to 2.101010 volt
X.1 to .2101010 volt

Resolution
1 microvolt on X1 range
.1 microvolt on X.1 range

TYPE 9144
DAUPHINEE POTENTIOMETER
Accuracy .001%
(10 times that of any known commercial accuracy available in similar equipment)

ELECTRICAL STANDARDS DEPARTMENTS come in all sizes and shapes. They may be in one corner of a bench someplace in an out of the way section of the plant. They may occupy floors of carefully air-conditioned, humidified rooms, with much equipment and many people or, they may be somewhere between these two extremes. However, fundamentally, they all exist for exactly one purpose — that is to show the relationship between electrical measurements made in the plant and those made at the National Bureau of Standards in Washington, D. C. or Boulder, Colorado.

Absolute measurements represent many man months for a single determination of current or resistance and, hence, are impractical for any except such national standardizing institutions such as NBS.

As soon as we base our concept of a standardizing operation on the theory that it is merely a comparison device between ourselves and NBS, several questions arise. First, does our standards department become merely a repository of a group of duplicate measuring equipment similar to that used in the plant, with this equipment continually shuttling back and forth between ourselves and the Bureau? Or, do we set up only one or two fundamental standards from the Bureau and derive the balance of our measurements from these standards and, if we do this, what are the units which we use for NBS transfer?

There are many versions of the answers to these questions. If we operate on the first proposed scheme of "keep a duplicate of everything and send it to the Bureau," we soon find ourselves in trouble. Many of the pieces of gear which we would like to use in this fashion do not have sufficient long-term stability to justify such travelling to and from the Bureau.

SENSITIVE RESEARCH
INSTRUMENT CORPORATION
NEW ROCHELLE, N. Y.
ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927
Symbol of Quality

Also, if enough people adopt this sort of philosophy, the Bureau of Standards would soon be so overloaded that it would be impossible for them to keep up with the tremendous number of routine measurements.

In many fields the NBS is already reaching this situation and, of necessity, they must then cut back on the routine measurements, in order to conserve their personnel for the more important and technically rewarding fields of working on tomorrow's measurements rather than today's routine calibrations.

Suppose we take the opposite approach and ask ourselves the following question: "What is the absolute minimum of cross checking equipment we require in order to maintain satisfactory wide range standards in our own plant for long periods of time." This question starts us looking at the overall long-term stability of the various electrical standards.

We find first, that saturated standard cells maintained at a constant temperature, provide an excellent long-term stability device for the maintaining of standard voltages. The working standard of voltage for the United States is maintained by the National Bureau of Standards in the form of about 30 saturated standard cells, most of which are about 40 years old.

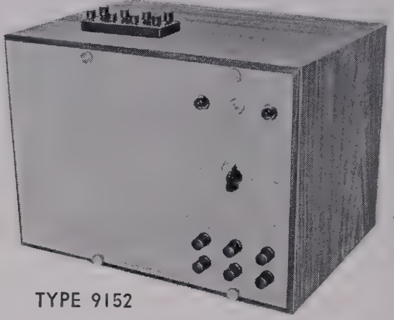
The assured drift rate of such a bank of saturated cells is such that yearly cross-checks by means of a portable standard with the Bureau of Standards in Washington or Boulder, would be ample to assure accuracies in the order of four or five parts per million. A look at unsaturated cells, however, shows that the great majority of these units have a steady drift which, unfortunately, may be either up or down and, hence, are not satisfactory for maintaining long-term stability although they are commonly used for interim measurements, plant standards, secondary working standards and things of this general class.

MODEL STV
Accuracy .01%

All types of standard cells are subject to damage from overload if they are abused when current is drawn from them in any appreciable amount. For this reason, many standards groups are changing to the Sensitive Research Model STV, standard voltage source, for secondary voltage standards instead of using unsaturated standard cells. The stability is comparable with such unsaturated cells and the fact that they are so immune to abuse, standing a short circuit indefinitely without damage, that they provide a more satisfactory reference. They will, of course, for utmost accuracy, require a regular check against a saturated bank for purposes of certification.

The inescapable conclusion then is that the Standards Department will require a bank of saturated standard cells in a constant temperature enclosure. The **COMMANDER*, type 9152, is an excellent example of such a device.

Having established our own voltage standard, we require either a current standard or a resistance standard in order to be able to accomplish all our measurements. Current is obviously a transient phenomenon and, hence, it is physically impossible to establish a current standard as such. However, when we look at resistance, we find that the four terminal NBS types of resistance as designed originally by Dr. Thomas of NBS, show excellent long-term stability and relative immunity to reasonable overloads and, hence, provide a very satisfactory basic standard. We find that yearly checks of such resistors are satisfactory to maintain accuracies in the general order of four or five parts per million.



Accommodates
Four
Standard
Cells

Temperature
variations held
within ± .01 C

TYPE 9152

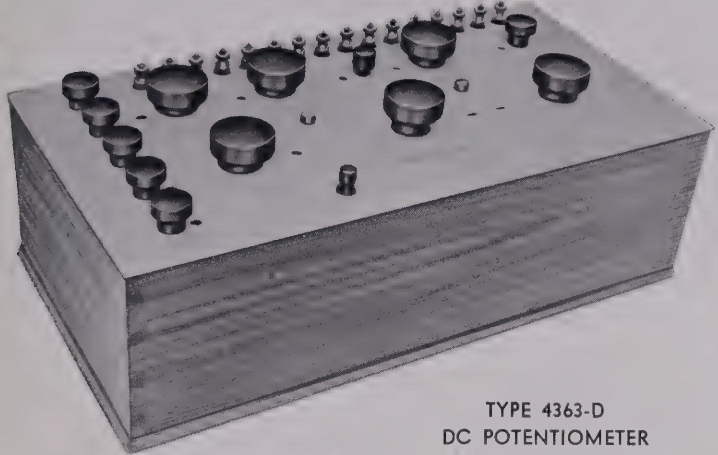
These four or five parts per million will probably not be obtained, or at least be completely assured, until one has a working history on the standard cells and resistances. In general, it is suggested that these instruments be certified by the Bureau of Standards at the time they go into service and at the end of six months, and then probably yearly thereafter will be ample to maintain this working accuracy.

Having established satisfactory basic standards for voltage and resistance and by combining the two, also standards of current, we find we need satisfactory devices for extending the ranges of operation. We need, for instance, to be able to measure voltages other than that of our standard cell bank, both higher and lower. Lower, of course, means a high accuracy potentiometer, which will cover the range from the general vicinity of standard cells, or a little above, on down through into the millivolt and, in some cases, microvolt range.

If we are to attempt to maintain comparisons, sufficiently valid to be reasonable for use with the standards just established, we require a potentiometric linearity at least comparable with the absolute values of resistance and voltage which we have set up. This means we need resolution of at least one part per million and we need absolute accuracy in terms of potentiometer linearity of possibly somewhat less than this.

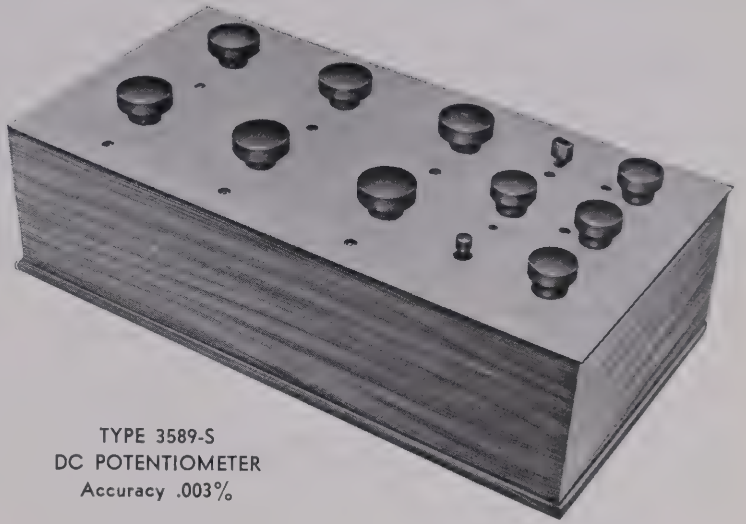
Such equipment is represented by the *COMMANDER* 9144, the *COMMANDER* 4363-D and the *COMMANDER* 3589-S potentiometers. All of these units have accuracies in this range and are satisfactory for measurements from a few microvolts up to one or two volts (except in the case of the 3589-S which has a top voltage of .11111 volts) with resolution and basic linearity sufficient for use with these standards.

*All "COMMANDER" instruments are manufactured for "Sensitive Research" by Guildline Instruments, Limited in Canada.



TYPE 4363-D
DC POTENTIOMETER
Accuracy .0015%

RANGES X1 to 1.901010 volts
X.1 to .1901010 volt
Resolution 1 microvolt on X1 Range
.1 microvolt on X.1 Range



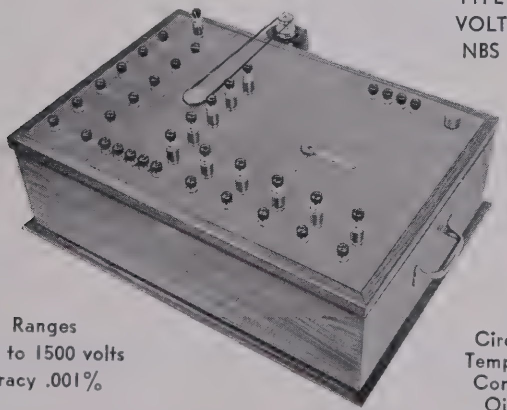
TYPE 3589-S
DC POTENTIOMETER
Accuracy .003%

RANGES X1 to .111110 volt
X.1 to .0111110 volt
Resolution 1 microvolt on X1 Range
.1 microvolt on X.1 Range

To extend the voltage range upward, the National Bureau of Standards has designed a volt box, described in their research paper No. RP 1419, in which the various ranges are so selected that it is possible not only to have a highly accurate and stable box, but to cross-check the various sections and literally bootstrap one's self up to as high as 1500 volts, by means of only a stable voltage source and an accurate potentiometer.

Volt boxes of this type are inherently more stable and accurate than the ordinary volt box due to the large number of bobbins employed on the higher volt ranges, maintaining a constant watts-per-square centimeter for all the resistors involved. Also, these devices are provided with a guard circuit which eliminates the possibility of leakage causing an error at higher voltages.

TYPE 9700
VOLT BOX
NBS Type



15 Ranges
.15 volt to 1500 volts
Accuracy .001%

Oil
Circulated
Temperature
Controlled
Oil Bath

The *COMMANDER* 9700 volt box and the *COMMANDER* 9700-A, reading to top voltages of 750 and 1500 volts respectively, are excellent examples of this type of volt box. Such volt boxes do not require Bureau certification in order to maintain working accuracies over long periods of time, because of the possibility of this self-check which is inherent in the design of the instrument. Hence, as far as voltages are concerned, a potentiometer of the types described will provide satisfactory extrapolation on down into the microvolt range from the standard cell voltage and the volt box will provide extrapolation up above this voltage to 1500 volts.

At this point, one additional factor immediately becomes pertinent. In extrapolating the voltage upward with the NBS type volt box, we have self-check provisions which can give us assured accuracies at the higher voltages. If we limit our choice of potentiometers to the *COMMANDER* type 9144, we have this self-same check provision built into the equipment allowing us to check the linearity of the main dials and standard cell circuits without recourse to any equipment other than another potentiometer with sufficient sensitivity to detect a microvolt and sufficient short-term stability to hold it during the course of a reading.

This second potentiometer does not have to have any accuracy or NBS checking of its own operation. The 9144 has built into its own circuitry all of the necessary switches and extra connections to provide complete external self-check procedures to assure the user of accuracy throughout its range without recourse to separate checks and, hence, any necessity for the potentiometer itself to go to the Bureau. To the best of our belief and knowledge, this 9144 is the only potentiometer of which this is completely true.

Now we reach the problem of extending our resistance ranges from possibly a single one ohm NBS standard which we had calibrated and certified at the Bureau. For this, one can use a Wenner Bridge or any one of several other devices to inter-compare resistors of similar values or resistors of nearby values.

We can ALSO use the *COMMANDER* 9144 potentiometer as a ratio device for checking of standard resistors. A unique feature of this potentiometer is inclusion in the standard cell side of the potentiometer positions for one volt, one-half volt, two-tenths volt and one-tenth volt. If, then, one sets up a common current through a known resistor and an unknown resistor and applies the potential from the known resistor to the nominal one volt position of the standardizing circuit on the potentiometer and the drop across the unknown resistor is applied to the normal EMF positions of the potentiometer, a balancing of the pot by means of the EMF dials will immediately indicate the exact ratio between the two resistors. These EMF dials can be direct reading then in resistance, requiring only the proper placing of a decimal point. This is true even though the standard resistor may have known corrections.

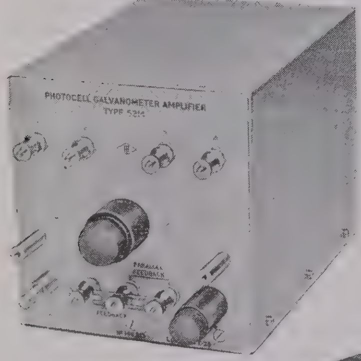
...MEASUREMENT IS THE BASIS OF PROGRESS...

There is included a special set of red figures on the standard cell dial which reads from zero to plus or minus 50 parts per million. When this dial is used for setting in the necessary corrections to the standard, the main dials become DIRECT READING in absolute resistance.

By this method which has a comparative accuracy in the order of one part per million, ranges of resistance of from twice the known standard resistance down to well below one-tenth of the standard resistance can readily be compared. By this method, it is relatively easy to extrapolate in steps of not more than ten to one, in either direction, from the basic one ohm NBS standard. By this method we now can have working standards with a practically infinite range of resistance, a wide range of voltage and we still have not exhausted the possibility of this universal piece of test equipment as the *COMMANDER* 9144 potentiometer.

In order to extend the accuracy of our saturated standard cell bank out into the plant, we would normally use other saturated cells for the highest accuracy and for somewhat lower accuracies either the SRIC Model STV, or unsaturated standard cells. We need a means of comparing these to our saturated bank.

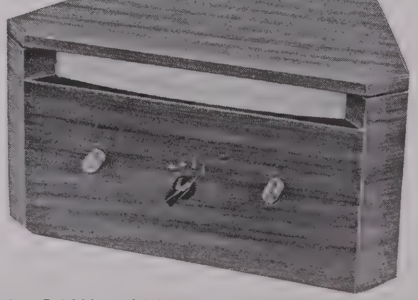
For this use, the *COMMANDER* 9144 makes an excellent standard cell comparitor. The simplest method of using this is to connect four circuits to the EMF terminals of the 9144 potentiometer through a 9145 thermo free switch. Connect to one position terminals of the standard cell to be measured and to the other three positions, three of the cells in our standard cell bank. By switching to any one of the three standard cells in the bank, the EMF dials are set to its known value and the current in the potentiometer balanced without recourse to the standardizing circut of the potentiometer. For utmost accuracy, we then cross-check the two other cells of the saturated cell bank. Without restandardizing the operating current in the potentiometer, switch to the unknown cell to be certified, rebalancing by means of the EMF dials only, the value of the unknown cell is determined directly from the EMF readings. These readings are readily made to one microvolt directly from the dials.



Current Sensitivity
up to
350,000 mm
per microampere

TYPE 5214

PHOTO CELL
GALVANOMETER
AMPLIFIER



TYPE SR-21 GALVANOMETER
Sensitivity .002 microamperes per mm

If a *COMMANDER* 5214 galvanometer amplifier is used, preferably with its companion SR 21 secondary galvanometer, galvanometer sensitivity can be made sufficiently great that extrapolation between the one microvolt steps on the finest dial can readily be made to much better than a tenth of a microvolt. This resolution is very comparable with any other possible standard cell comparitor device and, of course, we have had to have only one single potentiometer to accomplish this.

It is obvious from the above descriptions that we consider the *COMMANDER* Model 9144 as the heart of a standards operation, because of its use both as a potentiometer, as a resistor comparitor, as a standard cell comparitor and because of its self-check features. For these applications where you require its use as only a potentiometer on a full-time basis, then one should very well consider the 4363-D which is very nearly its equal as a potentiometer. If one has full-time usage for a straight resistance comparitor, then one of the Wenner comparitor bridges is slightly faster and more convenient. If one has full-time use for a standard cell comparitor, some of the specialized standard cell comparitors on the market are a little bit faster and more convenient for this operation.

Unless the standards department has sufficient work to keep three separate instruments in full time use, the 9144 is the logical choice. The 9144 doing all three jobs, will keep the small plant standards investment at a minimum and still keep complete coverage available. Also, because of its wide-range facilities, it becomes an excellent second device for the extremely well-equipped department.

For instance, if one had all three of the equipments mentioned — the potentiometer, the comparitor bridge, the standard cell comparitor — in order to have spares, one would need three separate spares. The 9144 would provide alternate facilities for any one of the three when required. In other words, we are enthusiastic about the possibilities of this instrument.

The combination of a 9144 potentiometer, a 5214 galvanometer amplifier, and SR 21 galvanometer for use with the 5214, an SR 4 galvanometer for use in the standard cell circuit for uses requiring simultaneous main dial and standard dial balance and a 9145 thermo free switch for switching inputs to the potentiometer constitute the heart of a complete standards set-up. The user of such equipment can then be assured of measurements to the highest degree of accuracy obtainable today.

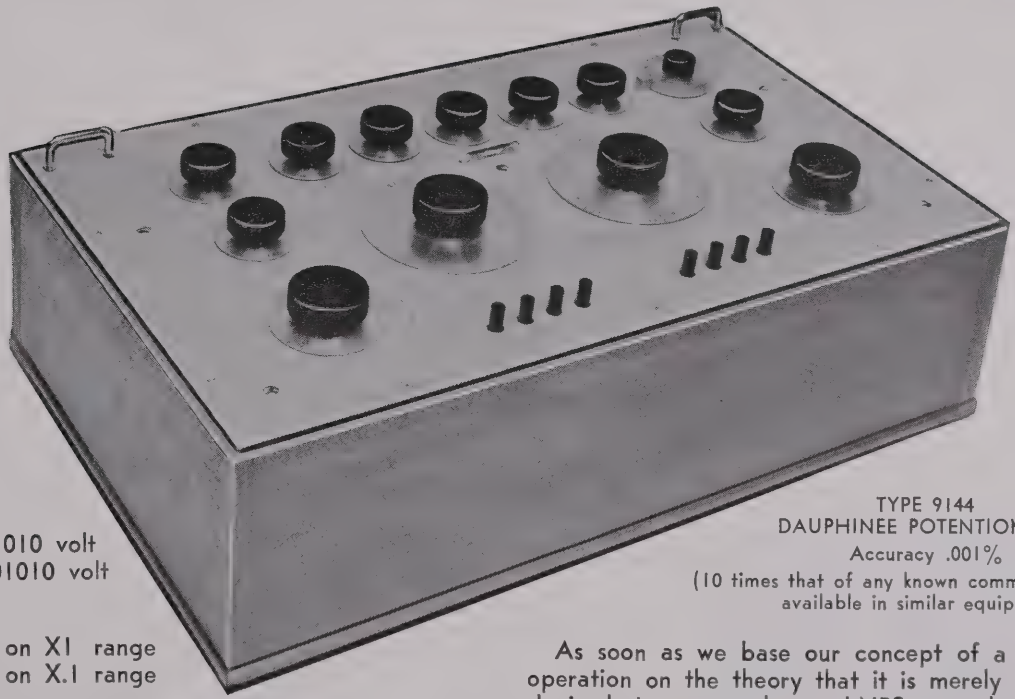
These instruments are described in detail in our brochure on ELECTRICAL MEASURING STANDARDS, a copy of which is yours for the asking. Our Model STV standard volt is described in our general instrument catalog.

Sensitive

Electrical MEASUREMENTS

VOLUME 28 FEBRUARY, 1961 NUMBER 2

A SELF SUFFICIENT
ELECTRICAL STANDARDS PROGRAM



Ranges
XI to 2.101010 volt
X.1 to .2101010 volt

Resolution
1 microvolt on XI range
.1 microvolt on X.1 range

TYPE 9144
DAUPHINEE POTENTIOMETER
Accuracy .001%
(10 times that of any known commercial accuracy available in similar equipment)

ELECTRICAL STANDARDS DEPARTMENTS come in all sizes and shapes. They may be in one corner of a bench someplace in an out of the way section of the plant. They may occupy floors of carefully air-conditioned, humidified rooms, with much equipment and many people or, they may be somewhere between these two extremes. However, fundamentally, they all exist for exactly one purpose — that is to show the relationship between electrical measurements made in the plant and those made at the National Bureau of Standards in Washington, D. C. or Boulder, Colorado.

Absolute measurements represent many man months for a single determination of current or resistance and, hence, are impractical for any except such national standardizing institutions such as NBS.

As soon as we base our concept of a standardizing operation on the theory that it is merely a comparison device between ourselves and NBS, several questions arise. First, does our standards department become merely a repository of a group of duplicate measuring equipment similar to that used in the plant, with this equipment continually shuttling back and forth between ourselves and the Bureau? Or, do we set up only one or two fundamental standards from the Bureau and derive the balance of our measurements from these standards and, if we do this, what are the units which we use for NBS transfer?

There are many versions of the answers to these questions. If we operate on the first proposed scheme of "keep a duplicate of everything and send it to the Bureau," we soon find ourselves in trouble. Many of the pieces of gear which we would like to use in this fashion do not have sufficient long-term stability to justify such travelling to and from the Bureau.

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y. *ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927*

Symbol of Quality

Also, if enough people adopt this sort of philosophy, the Bureau of Standards would soon be so overloaded that it would be impossible for them to keep up with the tremendous number of routine measurements.

In many fields the NBS is already reaching this situation and, of necessity, they must then cut back on the routine measurements, in order to conserve their personnel for the more important and technically rewarding fields of working on tomorrow's measurements rather than today's routine calibrations.

Suppose we take the opposite approach and ask ourselves the following question: "What is the absolute minimum of cross checking equipment we require in order to maintain satisfactory wide range standards in our own plant for long periods of time." This question starts us looking at the overall long-term stability of the various electrical standards.

We find first, that saturated standard cells maintained at a constant temperature, provide an excellent long-term stability device for the maintaining of standard voltages. The working standard of voltage for the United States is maintained by the National Bureau of Standards in the form of about 30 saturated standard cells, most of which are about 40 years old.

The assured drift rate of such a bank of saturated cells is such that yearly cross-checks by means of a portable standard with the Bureau of Standards in Washington or Boulder, would be ample to assure accuracies in the order of four or five parts per million. A look at unsaturated cells, however, shows that the great majority of these units have a steady drift which, unfortunately, may be either up or down and, hence, are not satisfactory for maintaining long-term stability although they are commonly used for interim measurements, plant standards, secondary working standards and things of this general class.

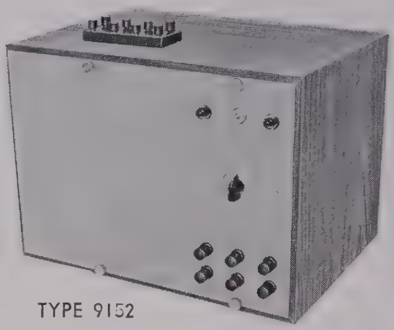
MODEL STV
Accuracy .01%

All types of standard cells are subject to damage from overload if they are abused when current is drawn from them in any appreciable amount. For this reason, many standards groups are changing to the Sensitive Research Model STV, standard voltage source, for secondary voltage standards instead of using unsaturated standard cells. The stability is comparable with such unsaturated cells and the fact that they are so immune to abuse, standing a short circuit indefinitely without damage, that they provide a more satisfactory reference. They will, of course, for utmost accuracy, require a regular check against a saturated bank for purposes of certification.

The inescapable conclusion then is that the Standards Department will require a bank of saturated standard cells in a constant temperature enclosure. The **COMMANDER*, type 9152, is an excellent example of such a device.

Having established our own voltage standard, we require either a current standard or a resistance standard in order to be able to accomplish all our measurements. Current is obviously a transient phenomenon and, hence, it is physically impossible to establish a current standard as such. However, when we look at resistance, we find that the four terminal NBS types of resistance as designed originally by Dr. Thomas of NBS, show excellent long-term stability and relative immunity to reasonable overloads and, hence, provide a very satisfactory basic standard. We find that yearly checks of such resistors are satisfactory to maintain accuracies in the general order of four or five parts per million.

Accommodates
Four
Standard
Cells



Temperature variations held within ± .01 C

TYPE 9152

These four or five parts per million will probably not be obtained, or at least be completely assured, until one has a working history on the standard cells and resistances. In general, it is suggested that these instruments be certified by the Bureau of Standards at the time they go into service and at the end of six months, and then probably yearly thereafter will be ample to maintain this working accuracy.

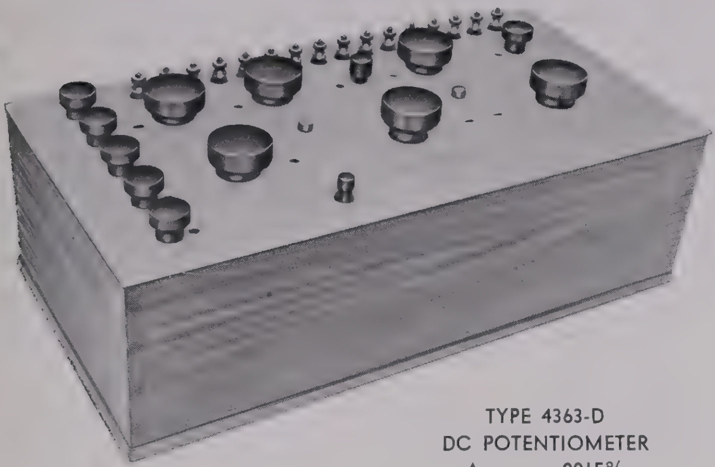
Having established satisfactory basic standards for voltage and resistance and by combining the two, also standards of current, we find we need satisfactory devices for extending the ranges of operation. We need, for instance, to be able to measure voltages other than that of our standard cell bank, both higher and lower. Lower, of course, means a high accuracy potentiometer, which will cover the range from the general vicinity of standard cells, or a little above, on down through into the millivolt and, in some cases, microvolt range.

If we are to attempt to maintain comparisons, sufficiently valid to be reasonable for use with the standards just established, we require a potentiometric linearity at least comparable with the absolute values of resistance and voltage which we have set up. This means we need resolution of at least one part per million and we need absolute accuracy in terms of potentiometer linearity of possibly somewhat less than this.

Such equipment is represented by the *COMMANDER* 9144, the *COMMANDER* 4363-D and the *COMMANDER* 3589-S potentiometers. All of these units have accuracies in this range and are satisfactory for measurements from a few microvolts up to one or two volts (except in the case of the 3589-S which has a top voltage of .11111 volts) with resolution and basic linearity sufficient for use with these standards.

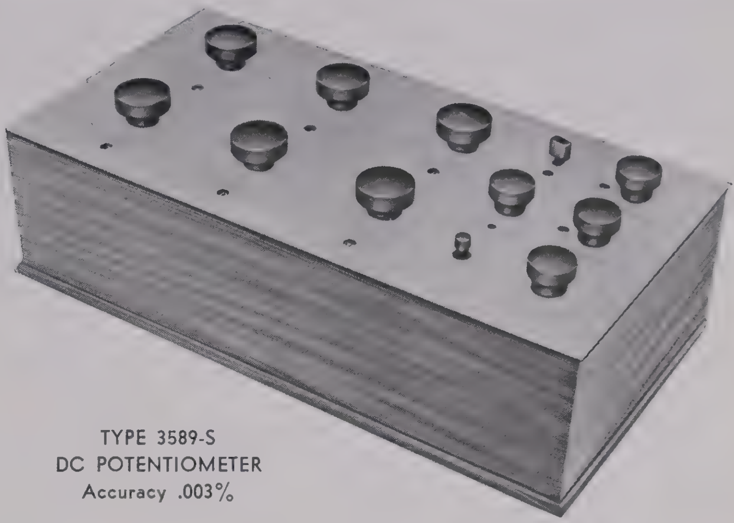
*All "COMMANDER" instruments are manufactured for "Sensitive Research" by Guildline Instruments, Limited in Canada.

...INSTRUMENTS CERTIFY NEW KNOWLEDGE...



TYPE 4363-D
DC POTENTIOMETER
Accuracy .0015%

RANGES X1 to 1.901010 volts
X.1 to .1901010 volt
Resolution 1 microvolt on X1 Range
.1 microvolt on X.1 Range

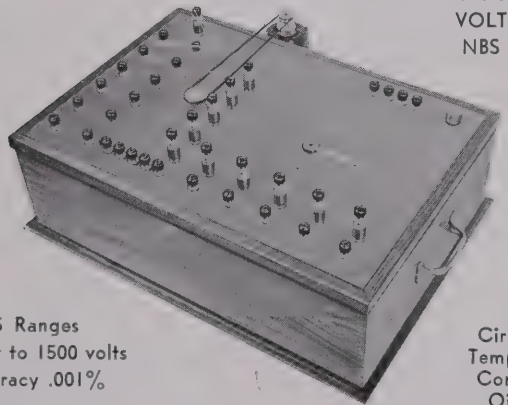


TYPE 3589-S
DC POTENTIOMETER
Accuracy .003%

RANGES X1 to .111110 volt
X.1 to .0111110 volt
Resolution 1 microvolt on X1 Range
.1 microvolt on X.1 Range

To extend the voltage range upward, the National Bureau of Standards has designed a volt box, described in their research paper No. RP 1419, in which the various ranges are so selected that it is possible not only to have a highly accurate and stable box, but to cross-check the various sections and literally bootstrap one's self up to as high as 1500 volts, by means of only a stable voltage source and an accurate potentiometer.

Volt boxes of this type are inherently more stable and accurate than the ordinary volt box due to the large number of bobbins employed on the higher volt ranges, maintaining a constant watts-per-square centimeter for all the resistors involved. Also, these devices are provided with a guard circuit which eliminates the possibility of leakage causing an error at higher voltages.



TYPE 9700
VOLT BOX
NBS Type

15 Ranges
.15 volt to 1500 volts
Accuracy .001%

Oil
Circulated
Temperature
Controlled
Oil Bath

The *COMMANDER* 9700 volt box and the *COMMANDER* 9700-A, reading to top voltages of 750 and 1500 volts respectively, are excellent examples of this type of volt box. Such volt boxes do not require Bureau certification in order to maintain working accuracies over long periods of time, because of the possibility of this self-check which is inherent in the design of the instrument. Hence, as far as voltages are concerned, a potentiometer of the types described will provide satisfactory extrapolation on down into the microvolt range from the standard cell voltage and the volt box will provide extrapolation up above this voltage to 1500 volts.

At this point, one additional factor immediately becomes pertinent. In extrapolating the voltage upward with the NBS type volt box, we have self-check provisions which can give us assured accuracies at the higher voltages. If we limit our choice of potentiometers to the *COMMANDER* type 9144, we have this self-same check provision built into the equipment allowing us to check the linearity of the main dials and standard cell circuits without recourse to any equipment other than another potentiometer with sufficient sensitivity to detect a microvolt and sufficient short-term stability to hold it during the course of a reading.

This second potentiometer does not have to have any accuracy or NBS checking of its own operation. The 9144 has built into its own circuitry all of the necessary switches and extra connections to provide complete external self-check procedures to assure the user of accuracy throughout its range without recourse to separate checks and, hence, any necessity for the potentiometer itself to go to the Bureau. To the best of our belief and knowledge, this 9144 is the only potentiometer of which this is completely true.

Now we reach the problem of extending our resistance ranges from possibly a single one ohm NBS standard which we had calibrated and certified at the Bureau. For this, one can use a Wenner Bridge or any one of several other devices to inter-compare resistors of similar values or resistors of nearby values.

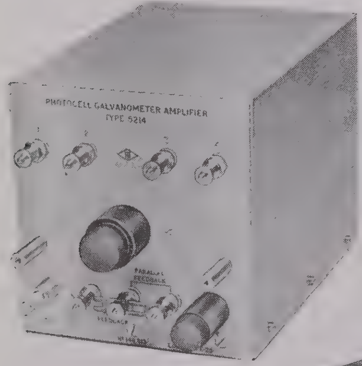
We can ALSO use the *COMMANDER* 9144 potentiometer as a ratio device for checking of standard resistors. A unique feature of this potentiometer is inclusion in the standard cell side of the potentiometer positions for one volt, one-half volt, two-tenths volt and one-tenth volt. If, then, one sets up a common current through a known resistor and an unknown resistor and applies the potential from the known resistor to the nominal one volt position of the standardizing circuit on the potentiometer and the drop across the unknown resistor is applied to the normal EMF positions of the potentiometer, a balancing of the pot by means of the EMF dials will immediately indicate the exact ratio between the two resistors. These EMF dials can be direct reading then in resistance, requiring only the proper placing of a decimal point. This is true even though the standard resistor may have known corrections.

There is included a special set of red figures on the standard cell dial which reads from zero to plus or minus 50 parts per million. When this dial is used for setting in the necessary corrections to the standard, the main dials become DIRECT READING in absolute resistance.

By this method which has a comparative accuracy in the order of one part per million, ranges of resistance of from twice the known standard resistance down to well below one-tenth of the standard resistance can readily be compared. By this method, it is relatively easy to extrapolate in steps of not more than ten to one, in either direction, from the basic one ohm NBS standard. By this method we now can have working standards with a practically infinite range of resistance, a wide range of voltage and we still have not exhausted the possibility of this universal piece of test equipment as the *COMMANDER* 9144 potentiometer.

In order to extend the accuracy of our saturated standard cell bank out into the plant, we would normally use other saturated cells for the highest accuracy and for somewhat lower accuracies either the SRIC Model STV, or unsaturated standard cells. We need a means of comparing these to our saturated bank.

For this use, the *COMMANDER* 9144 makes an excellent standard cell comparitor. The simplest method of using this is to connect four circuits to the EMF terminals of the 9144 potentiometer through a 9145 thermo free switch. Connect to one position terminals of the standard cell to be measured and to the other three positions, three of the cells in our standard cell bank. By switching to any one of the three standard cells in the bank, the EMF dials are set to its known value and the current in the potentiometer balanced without recourse to the standardizing circut of the potentiometer. For utmost accuracy, we then cross-check the two other cells of the saturated cell bank. Without restandardizing the operating current in the potentiometer, switch to the unknown cell to be certified, rebalancing by means of the EMF dials only, the value of the unknown cell is determined directly from the EMF readings. These readings are readily made to one microvolt directly from the dials.



Current Sensitivity
up to
350,000 mm
per microampere

TYPE 5214

PHOTO CELL
GALVANOMETER
AMPLIFIER

TYPE SR-21 GALVANOMETER
Sensitivity .002 microamperes per mm

If a *COMMANDER* 5214 galvanometer amplifier is used, preferably with its companion SR 21 secondary galvanometer, galvanometer sensitivity can be made sufficiently great that extrapolation between the one microvolt steps on the finest dial can readily be made to much better than a tenth of a microvolt. This resolution is very comparable with any other possible standard cell comparitor device and, of course, we have had to have only one single potentiometer to accomplish this.

It is obvious from the above descriptions that we consider the *COMMANDER* Model 9144 as the heart of a standards operation, because of its use both as a potentiometer, as a resistor comparitor, as a standard cell comparitor and because of its self-check features. For these applications where you require its use as only a potentiometer on a full-time basis, then one should very well consider the 4363-D which is very nearly its equal as a potentiometer. If one has full-time usage for a straight resistance comparitor, then one of the Wenner comparitor bridges is slightly faster and more convenient. If one has full-time use for a standard cell comparitor, some of the specialized standard cell comparitors on the market are a little bit faster and more convenient for this operation.

Unless the standards department has sufficient work to keep three separate instruments in full time use, the 9144 is the logical choice. The 9144 doing all three jobs, will keep the small plant standards investment at a minimum and still keep complete coverage available. Also, because of its wide-range facilities, it becomes an excellent second device for the extremely well-equipped department.

For instance, if one had all three of the equipments mentioned — the potentiometer, the comparitor bridge, the standard cell comparitor — in order to have spares, one would need three separate spares. The 9144 would provide alternate facilities for any one of the three when required. In other words, we are enthusiastic about the possibilities of this instrument.

The combination of a 9144 potentiometer, a 5214 galvanometer amplifier, and SR 21 galvanometer for use with the 5214, an SR 4 galvanometer for use in the standard cell circuit for uses requiring simultaneous main dial and standard dial balance and a 9145 thermo free switch for switching inputs to the potentiometer constitute the heart of a complete standards set-up. The user of such equipment can then be assured of measurements to the highest degree of accuracy obtainable today.

These instruments are described in detail in our brochure on ELECTRICAL MEASURING STANDARDS, a copy of which is yours for the asking. Our Model STV standard volt is described in our general instrument catalog.

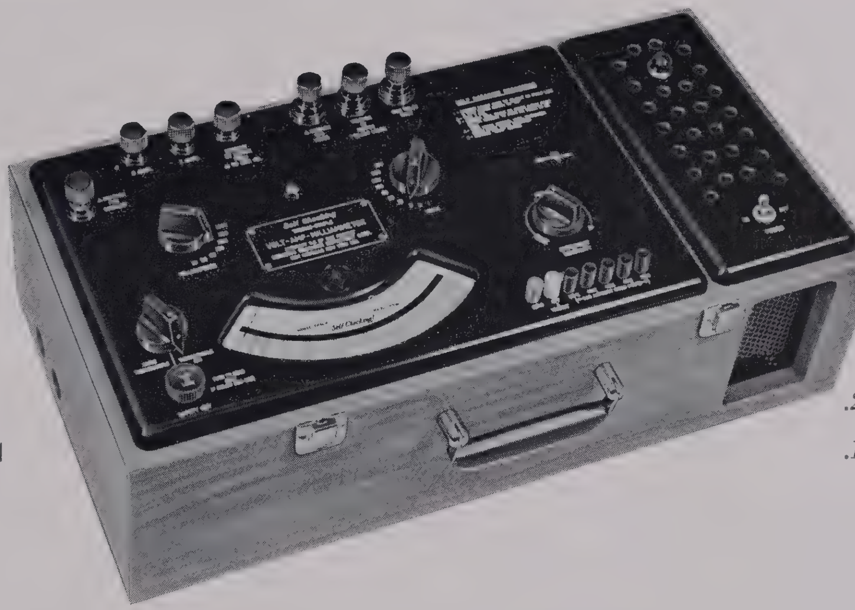
Electrical MEASUREMENTS

VOLUME 28 JANUARY, 1961 NUMBER 1

A New Self Checking INSTRUMENT

MODEL **THACH**

With
one or two
Thermocouples



DOUBLE PIVOTED
MOVING COIL SYSTEM
USING
DIAMOND PIVOTS!

ACCURACY

.2 of 1% DC to 4000 Cycles

.1 of 1% DC to 4000 Cycles
(at Multicheck Points)

Above 4000 Cycles
Accuracy is
1% to 15,000 Cycles

We have been printing our company bulletin "ELECTRICAL MEASUREMENTS" since the year 1934.

In previous issues we have discussed the use of thermocouples for AC measurement in many of its phases. We have discussed our Model A and Model AU instruments for the measurement of AC voltages and currents in the low frequency and audio frequency ranges of operation with accuracies from .5 to .75 of one percent.

We have described the use of the thermocouple in extremely high frequencies when discussing our Model RFV in which both the thermocouple and the resistors were designed primarily to have high frequency response and thus extend the area of measurement. We have combined this high frequency response with a built-in DC calibrator in our Model RFVC radio frequency voltage calibrator previously described. In that instrument, the prime purpose was to provide calibration voltages for vacuum-tube voltmeters up to extremely high frequencies (10 megacycles).

SENSITIVE RESEARCH
INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

Symbol of Quality

In other issues, we have described our complete line of calibration consoles, in which thermocouples are used in a transfer mechanism for measurement of AC. The circuits used in the test consoles have been of the so-called "Hermach" type. In these instruments, the thermocouple provides the transfer device, and the ultimate accuracy is dependent only upon the short-term stability of the thermocouple. Special compensations are made to take care of variations in thermocouple heater resistance. These consoles provide about the ultimate in basic accuracy of AC measurement (.05% of any reading).

On one hand, we have the calibration consoles with their .05% accuracy and somewhat slow operating procedures. On the other hand, we have the very simple direct reading instruments such as the Model A with their half percent accuracy.

The gap between the above two instruments is very well filled by our well known Model THACH self checking AC - DC instruments. These instruments, available in models to cover very wide ranges of current and voltage, provide basic accuracies of one-tenth and two-tenths percent.

The Model THACH self checking instrument combines to a very satsifactory degree the simplicity of the direct reading thermocouple instruments and includes an internal reference source for standardization purposes which allows a substantially higher accuracy than would be possible with the thermal instrument alone.

The THACH in the Models 1-X and 2-X consists of a multirange thermocouple instrument. Included in the same case is a pair of mercury cells and rheostats by means of which a DC current can be applied to the thermocouple and also through a monitor resistance. Across the monitor resistance is a built-in standard cell and galvanometer. Recertification of the thermal instrument is accomplished by adjusting the current from the internal battery supply to that point at which the drop across the monitor resistance exactly equals the voltage of the standard cell, as indicated by a zero deflection on the galvanometer.

At this point, the current through the heater of the thermocouple is at exactly its correct operating value. If the pointer indication of the instrument does NOT indicate exactly full scale at this point, a "micro control" rheostat in the DC millivoltmeter side of the instrument, is adjusted for exact full-scale deflection.

In other words, the thermal instrument is recalibrated at the time of use in terms of the internal standard cell. This standardization takes place at full scale where the readability of the instrument is at a maximum.

In the THACH model 3-X and 4-X multicheck design, multicheck points, push button operated, are added to provide for standardization at 80 percent, 60 percent, 40 percent and 20 percent of full scale as well as the full-scale point. It will be noted from the catalog sections that the basic accuracy of the THACH models is two-tenths percent. The reasons for these accuracy variations are interesting and are points often neglected in the use of thermocouples.

Figure 2 shows variations in thermocouples at values well below the burn-out point. These curves are to be considered typical rather than specifically the action of any one particular couple. Up to 200 percent of rated current, it is seen that the heater resistance and the output show no appreciable change. These curves represent the junction millivolts and

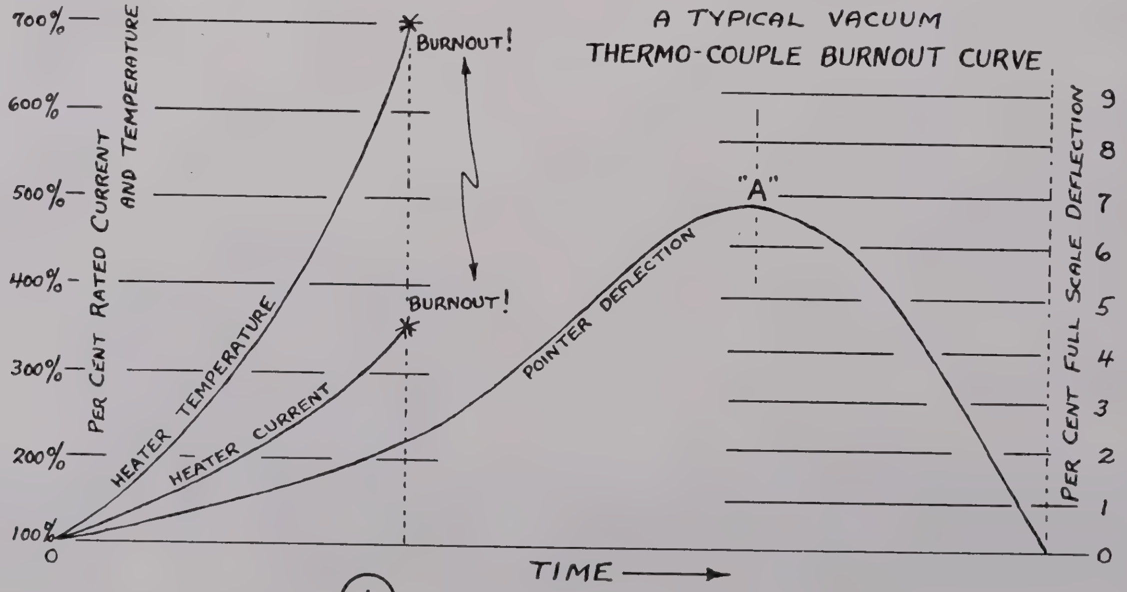
(Continued on next page)

◆

Though it may seem out of place at this point, we can't resist repeating the "I didn't burn it out, it never reached full scale," curves which we have previously published and apply to all thermocouple instruments.

This is our Figure No. 1. These curves show heater current and heater temperature rising rapidly with overload to a burn-out point. They, in fact, reach this point so fast that the pointer's deflection is not able to indicate it. The pointer deflection continues on upward after burn-out due to its own mechanical inertia and to some slight retention of heat in the junction of the now open circuited heater.

As soon as these two factors are spent, the pointer stops moving upward and falls back to zero and may, as shown, never reach full scale. These are facts well worth repeating, but let us look with somewhat more detail into what can happen to these thermocouples under overload conditions.

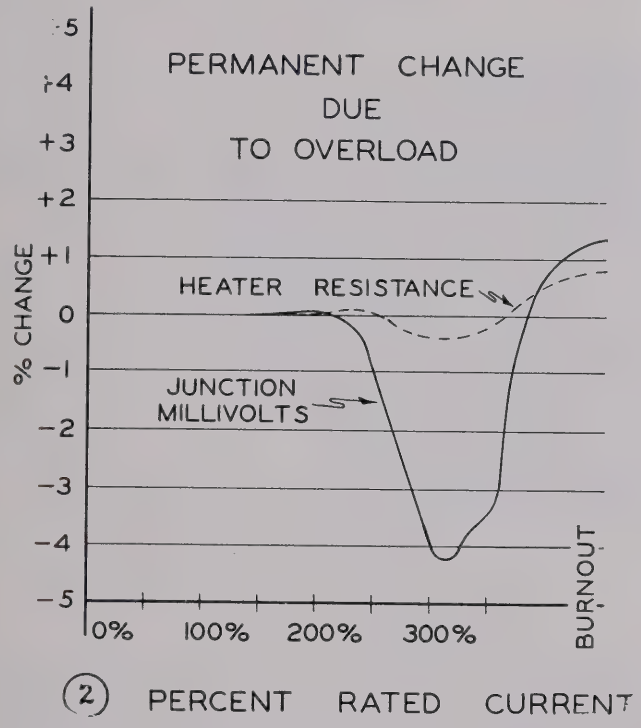


①

heater resistance measured at rated current *after* the application of overloads of the amount indicated.

It is obvious that overloads of up to 200 percent of rated current have no appreciable effect on the long-term accuracy of such an instrument. However, at slightly more than 200 percent, it will be noticed that two effects begin to occur. One, a permanent change in the value of heater resistance, going down for overloads of up to about 350 percent and then showing a marked rise for values of just under the burn-out point. In similar fashion, the junction output changes to marked degree in terms of percent change of instrument reading. There is a sharp drop beginning at slightly more than 200 percent overload and continuing to just before burn-out at which point a slight gain is shown.

If the effect were purely that of a change in junction output, a rheostat in the micro-control position could completely recertify the instrument. However, because of the multi ranges of this instrument, the thermocouple is of necessity shunted. This shunting provides a variation from the theoretical square law scale because the heater resistance changes with the amount of current through it. The scale being individually hand-calibrated takes this factor into account.

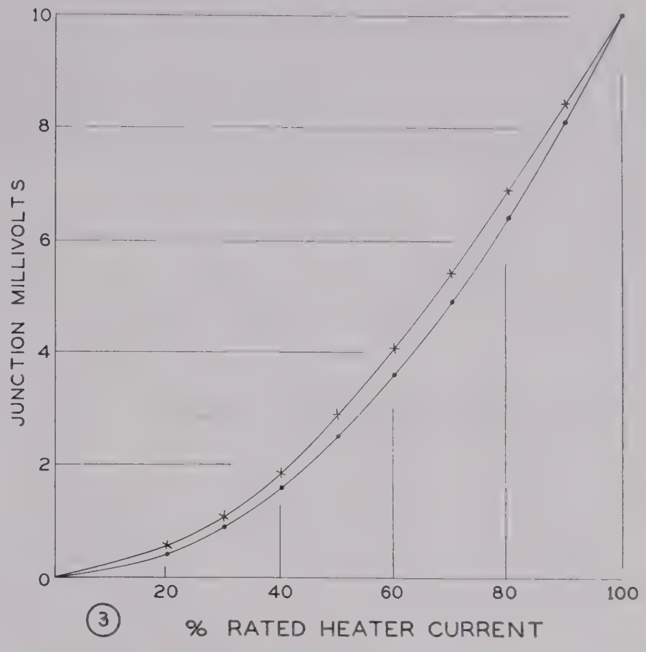


②

If now we change the heater resistance because of overload and merely readjust so that any single point on the scale is correct, we find that these built-in distortions in the scale are not correct under the new conditions.

Figure 3 shows graphically what happens. The calibration points shown by crosses are the original calibration of the instrument. After overloading the couple more than 200 percent so as to show a change in both heater resistance and junction output, the junction output has been readjusted for full scale.

It is readily seen that none of the other points on the scale agree with the original values and hence an inherent reading error has been introduced even though the instrument is recertified at its full scale point.



③

The range of the micro control on our Model THACH is deliberately limited in order to keep this effect within bounds. For the Models 1-X and 2-X, anything in the way of thermocouple changes which can be corrected by the limited range of the micro control will not show up in instrument errors greater than two-tenths percent. In the Models 3-X and 4-X, the same effect is present. However by choosing the standardizing points to be as close as possible to the point on the scale being read, significantly greater accuracies can be obtained, since all check points can be adjusted to considerably better than one-tenth of one percent. (3-X and 4-X push button design.)

In this new Model THACH (code MULTILABSTV) — (see page 1) all of the valuable self-check features of the regular instrument have been retained, and, in addition, the operation has been remarkably speeded up and simplified. In place of the internal battery source to supply a DC current which must be standardized by means of a galvanometer and standard cell, a special solid state power supply has been built into the instrument. This supply, by means of special non-temperature sensitive Zener diode regulators, automatically provides standardized current to the thermocouple when the appropriate push button is operated.

The use of a reference supply eliminates the need of an internal galvanometer, an internal battery, an internal standard cell and the battery control rheostats. The instrument requires only switching to the check position and adjusting the micro-control if necessary to adjust the instrument to an exact calibration point. This makes the overall standardizing operation both simpler and more rapid and thus, significantly, increases the usefulness of the instrument. A source of 115 volt 60 cycle supply is necessary.

	Code	Scale Length		Price
MODEL THACH 0 - 10/20/50/100/200/500/1000 Ma /2/5 Amperes 0 - 1/2/5/10/20/50/100/200/500/1000 Volts	[redacted]	6.3" Weight 33 lbs. Uses Push Button Checking Procedures	Single Thermocouple	$1325.00*
			Two Thermocouples	1525.00**

The various THACH Models are completely described in our general instrument catalog, a copy of which is yours for the asking!

*MULTILABSTV **DEMULTILABSTV

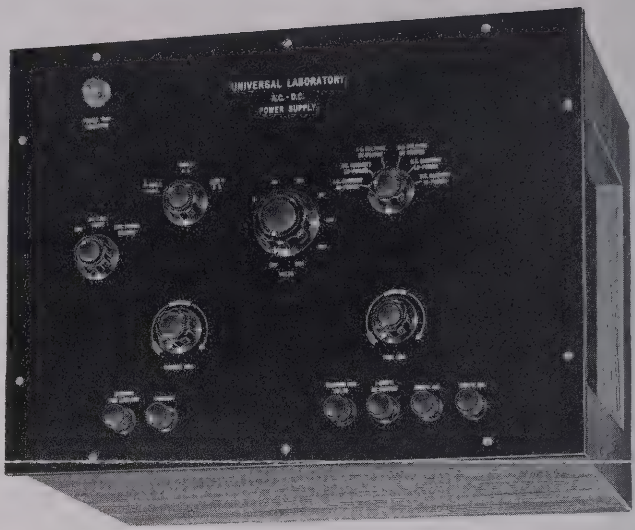
POWER SUPPLY FOR THACH

The "SENSITIVE RESEARCH" THACH POWER SUPPLY is an accessory designed to make the popular THACH AC-DC Laboratory Standard instrument into a versatile current and voltage calibrator.

This power supply is specifically designed with instrument calibration use in mind. The operating controls are such that extremely fine adjustment of voltages or currents can be had regardless of the range in use. The precision of adjustment is equally as good on the 1 volt range as it is on the 1000 volt range. In each case a fine and a coarse control give a resolution of at least .05% at any point on the instrument scale. This is a virtual necessity if really high accuracy is to be obtained in certification work.

In addition there is a built-in PROTECTIVE SYSTEM which will eliminate most of the possibilities of thermocouple burnout in the THACH instrument. An automatic relay system shuts off the power from the supply when ANY range switch is changed either on the instrument or on the power supply itself. In order to reactivate the system it is necessary to return the coarse control to zero and start all over in bringing up the power. This will prevent the major portion of the burnout difficulties which arise from inadvertently changing a range of the instrument.

This interlock also works when any range switch on the power supply is changed. Also provision is made to include shut down for any range change on the THACH instrument. This requires a modification of the THACH instrument and such modified instruments are in no way affected for normal operation. If the connecting cable which we supply, between instrument and power supply is removed, either instrument or power supply can be used independently.



MODEL THACH-PS

The power supply will furnish regulated AC voltages at 60 cycles or DC for all of the voltage and current ranges of the THACH instrument. In addition the supply can be fed from any 115 volt power at frequencies from 50 TO 2500 CYCLES and furnish the SAME controls for all ranges of the instrument. In operation at frequencies other than 60 cycles, no additional regulation is supplied over that of the line feeding the supply.

In addition to being an ideal complement to the THACH instrument, it is an excellent general purpose standardizing laboratory supply. The extremely precise control over the entire range of operation is a marked advantage for any calibration work.

SPECIFICATIONS

Output: AC or DC output selected by switch.

10 voltage ranges each with coarse and fine controls for 0 to 120% at full load and delivering a maximum of 175% at no load.

1, 2 or 5 volts at 300 ma.
10, 20 or 50 volts at 100 ma.
100, 200, 500 or 1000 volts at 25 ma.

Two current ranges (selected by switch) supply 0-5 A. at 15 watts maximum on low power position or 75 watts maximum on the high power.

Input: 90-135 volts, 60 cycle single phase, or 115 volts AC 50 to 2500 cycles from a regulated source.

Ripple: 2½% maximum for currents of 1 ampere or less. 7% RMS maximum for currents above 1 amp. (This can be reduced to 3% in all cases by simple series resistance added to meter being calibrated.)

Waveform: 60 cycle distortion 2½% total harmonic content plus line distortion.

Safety Interlock: Safety interlock on all internal switches to shut off power when supply range is changed. The model THACH is connected to the power supply by means of a cable which we supply so that the THACH switches are included in the safety interlock circuit. (THACH must be ordered with interlock or modified at the factory.)

Dimensions: 12¾" x 17" x 9" **Weight:** Approx. 59 lbs. **Code:** THAPOS **Price:** $995.00

THACH modification for interlocking use with this supply, $100.00 at time of original order. If added to existing instruments in the field the cost is $200.00

◆

For over 27 years we have published this company bulletin "ELECTRICAL MEASUREMENTS." In it we describe new instruments and measurement techniques. It is sent without cost to interested persons. If you have not been receiving this publication, please advise "SENSITIVE RESEARCH."

Electrical MEASUREMENTS

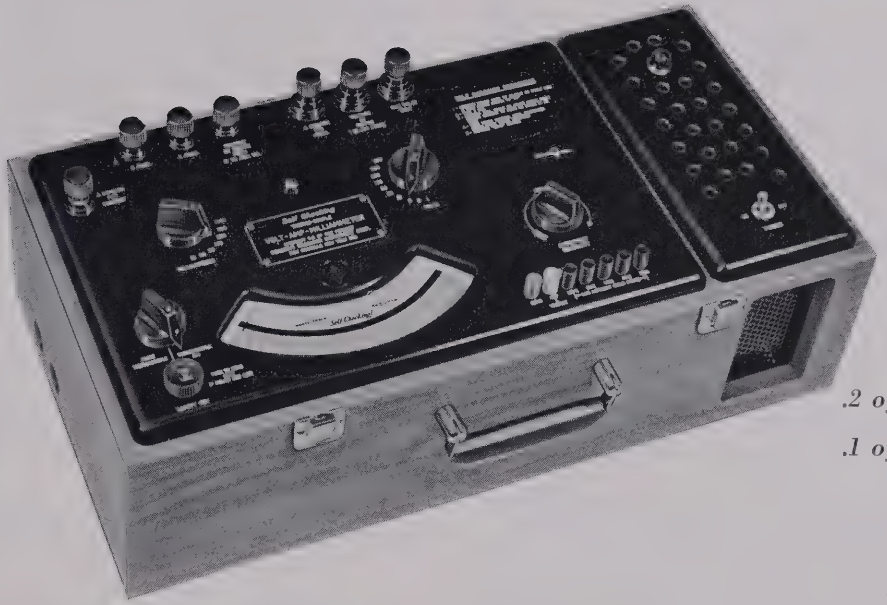
VOLUME 28 JANUARY, 1961 NUMBER 1

MAR 1 1961

A New Self Checking INSTRUMENT

MODEL **THACH**

With
one or two
Thermocouples



DOUBLE PIVOTED
MOVING COIL SYSTEM
USING
DIAMOND PIVOTS!

ACCURACY

.2 of 1% DC to 4000 Cycles

.1 of 1% DC to 4000 Cycles
(at Multicheck Points)

Above 4000 Cycles
Accuracy is
1% to 15,000 Cycles

We have been printing our company bulletin "ELECTRICAL MEASUREMENTS" since the year 1934.

In previous issues we have discussed the use of thermocouples for AC measurement in many of its phases. We have discussed our Model A and Model AU instruments for the measurement of AC voltages and currents in the low frequency and audio frequency ranges of operation with accuracies from .5 to .75 of one percent.

We have described the use of the thermocouple in extremely high frequencies when discussing our Model RFV in which both the thermocouple and the resistors were designed primarily to have high frequency response and thus extend the area of measurement. We have combined this high frequency response with a built-in DC calibrator in our Model RFVC radio frequency voltage calibrator previously described. In that instrument, the prime purpose was to provide calibration voltages for vacuum-tube voltmeters up to extremely high frequencies (10 megacycles).

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y. *ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927*

Symbol of Quality

In other issues, we have described our complete line of calibration consoles, in which thermocouples are used in a transfer mechanism for measurement of AC. The circuits used in the test consoles have been of the so-called "Hermach" type. In these instruments, the thermocouple provides the transfer device, and the ultimate accuracy is dependent only upon the short-term stability of the thermocouple. Special compensations are made to take care of variations in thermocouple heater resistance. These consoles provide about the ultimate in basic accuracy of AC measurement (.05% of any reading).

On one hand, we have the calibration consoles with their .05% accuracy and somewhat slow operating procedures. On the other hand, we have the very simple direct reading instruments such as the Model A with their half percent accuracy.

The gap between the above two instruments is very well filled by our well known Model THACH self checking AC - DC instruments. These instruments, available in models to cover very wide ranges of current and voltage, provide basic accuracies of one-tenth and two-tenths percent.

The Model THACH self checking instrument combines to a very satsifactory degree the simplicity of the direct reading thermocouple instruments and includes an internal reference source for standardization purposes which allows a substantially higher accuracy than would be possible with the thermal instrument alone.

The THACH in the Models 1-X and 2-X consists of a multi-range thermocouple instrument. Included in the same case is a pair of mercury cells and rheostats by means of which a DC current can be applied to the thermocouple and also through a monitor resistance. Across the monitor resistance is a built-in standard cell and galvanometer. Recertification of the thermal instrument is accomplished by adjusting the current from the internal battery supply to that point at which the drop across the monitor resistance exactly equals the voltage of the standard cell, as indicated by a zero deflection on the galvanometer.

At this point, the current through the heater of the thermocouple is at exactly its correct operating value. If the pointer indication of the instrument does NOT indicate exactly full scale at this point, a "micro control" rheostat in the DC millivoltmeter side of the instrument, is adjusted for exact full-scale deflection.

In other words, the thermal instrument is recalibrated at the time of use in terms of the internal standard cell. This standardization takes place at full scale where the readability of the instrument is at a maximum.

In the THACH model 3-X and 4-X multicheck design, multicheck points, push button operated, are added to provide for standardization at 80 percent, 60 percent, 40 percent and 20 percent of full scale as well as the full-scale point. It will be noted from the catalog sections that the basic accuracy of the THACH models is two-tenths percent. The reasons for these accuracy variations are interesting and are points often neglected in the use of thermocouples.

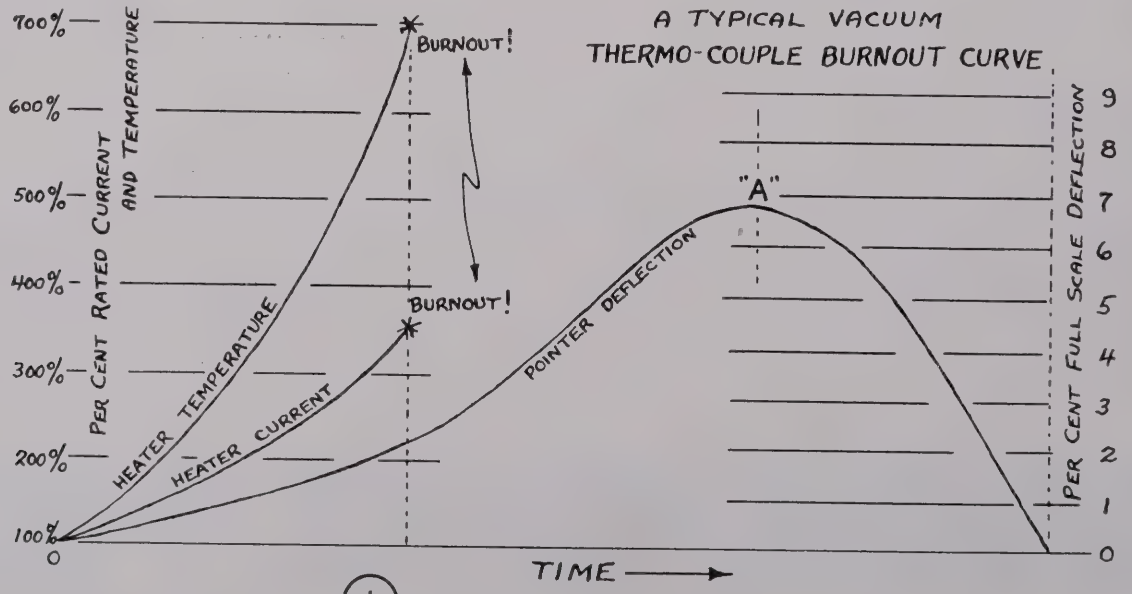
Figure 2 shows variations in thermocouples at values well below the burn-out point. These curves are to be considered typical rather than specifically the action of any one particular couple. Up to 200 percent of rated current, it is seen that the heater resistance and the output show no appreciable change. These curves represent the junction millivolts and

(Continued on next page)

Though it may seem out of place at this point, we can't resist repeating the "I didn't burn it out, it never reached full scale," curves which we have previously published and apply to all thermocouple instruments.

This is our Figure No. 1. These curves show heater current and heater temperature rising rapidly with overload to a burn-out point. They, in fact, reach this point so fast that the pointer's deflection is not able to indicate it. The pointer deflection continues on upward after burn-out due to its own mechanical inertia and to some slight retention of heat in the junction of the now open circuited heater.

As soon as these two factors are spent, the pointer stops moving upward and falls back to zero and may, as shown, never reach full scale. These are facts well worth repeating, but let us look with somewhat more detail into what can happen to these thermocouples under overload conditions.

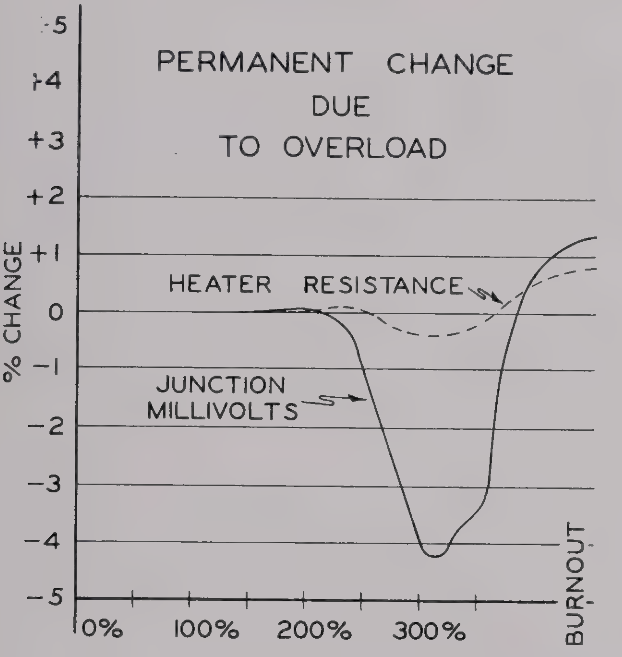


①

heater resistance measured at rated current *after* the application of overloads of the amount indicated.

It is obvious that overloads of up to 200 percent of rated current have no appreciable effect on the long-term accuracy of such an instrument. However, at slightly more than 200 percent, it will be noticed that two effects begin to occur. One, a permanent change in the value of heater resistance, going down for overloads of up to about 350 percent and then showing a marked rise for values of just under the burn-out point. In similar fashion, the junction output changes to marked degree in terms of percent change of instrument reading. There is a sharp drop beginning at slightly more than 200 percent overload and continuing to just before burn-out at which point a slight gain is shown.

If the effect were purely that of a change in junction output, a rheostat in the micro-control position could completely recertify the instrument. However, because of the multi ranges of this instrument, the thermocouple is of necessity shunted. This shunting provides a variation from the theoretical square law scale because the heater resistance changes with the amount of current through it. The scale being individually hand-calibrated takes this factor into account.

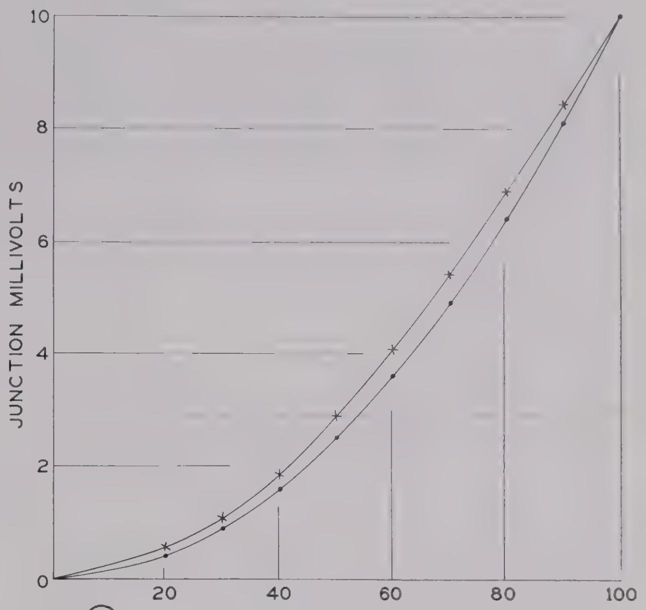


② PERCENT RATED CURRENT

If now we change the heater resistance because of overload and merely readjust so that any single point on the scale is correct, we find that these built-in distortions in the scale are not correct under the new conditions.

Figure 3 shows graphically what happens. The calibration points shown by crosses are the original calibration of the instrument. After overloading the couple more than 200 percent so as to show a change in both heater resistance and junction output, the junction output has been readjusted for full scale.

It is readily seen that none of the other points on the scale agree with the original values and hence an inherent reading error has been introduced even though the instrument is recertified at its full scale point.



③ % RATED HEATER CURRENT

The range of the micro control on our Model THACH is deliberately limited in order to keep this effect within bounds. For the Models 1-X and 2-X, anything in the way of thermocouple changes which can be corrected by the limited range of the micro control will not show up in instrument errors greater than two-tenths percent. In the Models 3-X and 4-X, the same effect is present. However by choosing the standardizing points to be as close as possible to the point on the scale being read, significantly greater accuracies can be obtained, since all check points can be adjusted to considerably better than one-tenth of one percent. (3-X and 4-X push button design.)

In this new Model THACH (code MULTILABSTV) — (see page 1) all of the valuable self-check features of the regular instrument have been retained, and, in addition, the operation has been remarkably speeded up and simplified. In place of the internal battery source to supply a DC current which must be standardized by means of a galvanometer and standard cell, a special solid state power supply has been built into the instrument. This supply, by means of special non-temperature sensitive Zener diode regulators, automatically provides standardized current to the thermocouple when the appropriate push button is operated.

The use of a reference supply eliminates the need of an internal galvanometer, an internal battery, an internal standard cell and the battery control rheostats. The instrument requires only switching to the check position and adjusting the micro-control if necessary to adjust the instrument to an exact calibration point. This makes the overall standardizing operation both simpler and more rapid and thus, significantly, increases the usefulness of the instrument. A source of 115 volt 60 cycle supply is necessary.

MODEL THACH	Code	Scale Length		Price
0 - 10/20/50/100/200/500/1000 Ma /2/5 Amperes 0 - 1/2/5/10/20/50/100/200/500/1000 Volts	[redacted]	6.3" Weight 33 lbs. Uses Push Button Checking Procedures	Single Thermocouple Two Thermocouples	$1325.00* 1525.00**

The various THACH Models are completely described in our general instrument catalog, a copy of which is yours for the asking!

*MULTILABSTV **DEMULTILABSTV

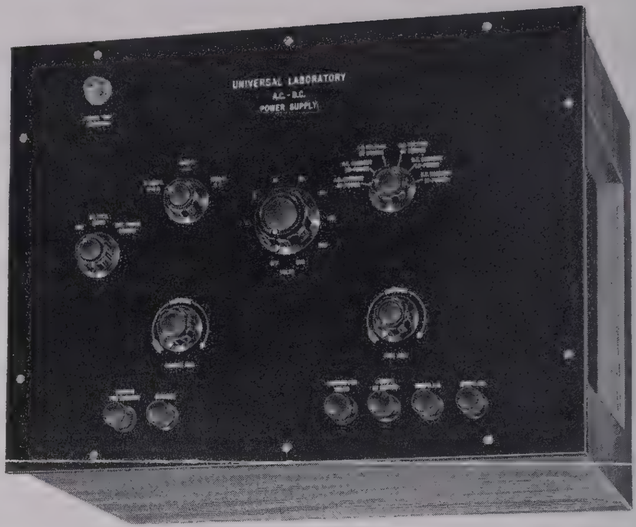
POWER SUPPLY FOR THACH

The "SENSITIVE RESEARCH" THACH POWER SUPPLY is an accessory designed to make the popular THACH AC-DC Laboratory Standard instrument into a versatile current and voltage calibrator.

This power supply is specifically designed with instrument calibration use in mind. The operating controls are such that extremely fine adjustment of voltages or currents can be had regardless of the range in use. The precision of adjustment is equally as good on the 1 volt range as it is on the 1000 volt range. In each case a fine and a coarse control give a resolution of at least .05% at any point on the instrument scale. This is a virtual necessity if really high accuracy is to be obtained in certification work.

In addition there is a built-in PROTECTIVE SYSTEM which will eliminate most of the possibilities of thermocouple burnout in the THACH instrument. An automatic relay system shuts off the power from the supply when ANY range switch is changed either on the instrument or on the power supply itself. In order to reactivate the system it is necessary to return the coarse control to zero and start all over in bringing up the power. This will prevent the major portion of the burnout difficulties which arise from inadvertently changing a range of the instrument.

This interlock also works when any range switch on the power supply is changed. Also provision is made to include shut down for any range change on the THACH instrument. This requires a modification of the THACH instrument and such modified instruments are in no way affected for normal operation. If the connecting cable which we supply, between instrument and power supply is removed, either instrument or power supply can be used independently.



MODEL THACH-PS

The power supply will furnish regulated AC voltages at 60 cycles or DC for all of the voltage and current ranges of the THACH instrument. In addition the supply can be fed from any 115 volt power at frequencies from 50 TO 2500 CYCLES and furnish the SAME controls for all ranges of the instrument. In operation at frequencies other than 60 cycles, no additional regulation is supplied over that of the line feeding the supply.

In addition to being an ideal complement to the THACH instrument, it is an excellent general purpose standardizing laboratory supply. The extremely precise control over the entire range of operation is a marked advantage for any calibration work.

SPECIFICATIONS

Output: AC or DC output selected by switch.

10 voltage ranges each with coarse and fine controls for 0 to 120% at full load and delivering a maximum of 175% at no load.

1, 2 or 5 volts at 300 ma.
10, 20 or 50 volts at 100 ma.
100, 200, 500 or 1000 volts at 25 ma.

Two current ranges (selected by switch) supply 0-5 A. at 15 watts maximum on low power position or 75 watts maximum on the high power.

Input: 90-135 volts, 60 cycle single phase, or 115 volts AC 50 to 2500 cycles from a regulated source.

Ripple: 2½% maximum for currents of 1 ampere or less. 7% RMS maximum for currents above 1 amp. (This can be reduced to 3% in all cases by simple series resistance added to meter being calibrated.)

Waveform: 60 cycle distortion 2½% total harmonic content plus line distortion.

Safety Interlock: Safety interlock on all internal switches to shut off power when supply range is changed. The model THACH is connected to the power supply by means of a cable which we supply so that the THACH switches are included in the safety interlock circuit. (THACH must be ordered with interlock or modified at the factory.)

Dimensions: 12¾" x 17" x 9" **Weight:** Approx. 59 lbs. **Code:** THAPOS **Price:** $995.00

THACH modification for interlocking use with this supply, $100.00 at time of original order. If added to existing instruments in the field the cost is $200.00

◆

For over 27 years we have published this company bulletin "ELECTRICAL MEASUREMENTS." In it we describe new instruments and measurement techniques. It is sent without cost to interested persons. If you have not been receiving this publication, please advise "SENSITIVE RESEARCH."

Electrical MEASUREMENTS

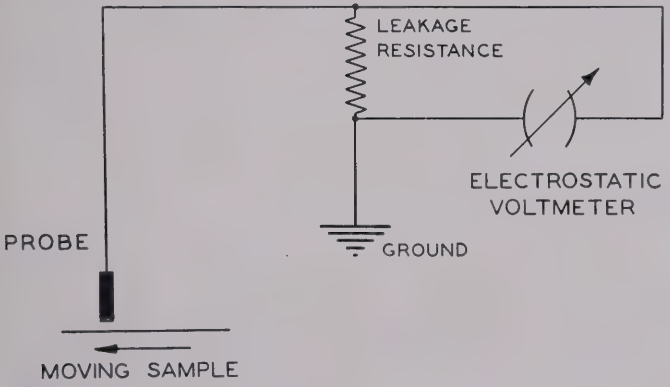
VOLUME 27 DECEMBER 1959 NUMBER 12

"POTPOURRI II"

Last December, we issued our first *"POTPOURRI"* in which we described a few of the problems and items of interest that continually pass across the desks of our Engineering Department. That issue of *ELECTRICAL MEASUREMENTS* was so well received, that *"POTPOURRI II"* has become necessary.

MORE ABOUT ELECTROSTATIC VOLTMETERS

Several people have lately come up with difficulties in measuring electrostatically developed voltages by means of our electrostatic voltmeters. One of the common complaints is, "I use a well insulated probe near a moving paper strip, plastic film, or similar static offender and the electrostatic voltmeter merely goes up scale and stays there even when I know the static is varying.



WHY? The answer is simple. The electrostatic instrument is extremely well insulated and if the probe is equally well insulated, there is no path for the *CHARGE OF THE INSTRUMENT* to leak off, and hence the pointer just sits up there at the peak voltage and stays put. The cure is equally simple. Shunt a very high value resistance across the instrument until the time constant is sufficiently low to allow the instrument to follow expected variations of the static charge. This resistor will reduce sensitivity but a satisfactory compromise "sensitivity" vs. "response" can usually be reached.

The second question asked many, many times is, "My probe works fine on the continuously running sheet, but when I try to investigate small variations on the stopped sheet, or the charge on a fixed solid, or any single charge phenomenon, I get no reaction even though I know there is a charge there.

Again, *"WHY?"* In this case the answer is only obvious after it is called to your attention. The electrostatic voltmeter can be considered as a perfect voltmeter in parallel with a capacitor. The voltmeter requires no energy but it *DOES* require energy to build up a charge on the capacitor.

If a probe touches one small spot on the surface of a charged body it can collect charge from only the very small area which it actually contacts. The suface is an insulator and charge from other portions of the surface cannot flow in to replace that at the contacted surface. In the case of the moving surface, the probe scans a large area as the surface moves below it and thus gives the effect of a very much larger area. The answer is to use a *LARGER PROBE AREA* for stationary measurements. When the probe area is sufficient to have a surface capacity equal to the capacitance of the instrument, then the charge on the surface contacted will divide equally between the probe and the instrument, and a reading of exactly one half the voltage present before the probe was placed will appear on the instrument.

VPA UNITS:

The SRIC Peak Voltage units (Type VPA) are a simple way to adapt our Model ESD or ESH electrostatic voltmeters to read peak voltages. In using these units it must be remembered that the VPA unit is a peak rectifier unit and that it delivers a DC voltage to the electrostatic instrument used with it for measurements of peak voltages. Because the instrument *SEES ONLY* a DC voltage regardless of the AC which may be applied to the VPA, only the lowest range of multirange ESD instruments are suitable for use with these units. The ranges, other than the lowest on this model ESD voltmeter, are obtained by means of capacity dividers and will give accurate readings only on AC voltages. Hence they should not be used with VPA units, (Additional information on these units available from us if desired.) Model ESH electrostatic voltmeters *DO NOT* have this limitation.

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

Symbol of Quality

SUPPRESSED ZERO INSTRUMENTS:

In some instances extra readability in an instrument scale may be needed for either faster reading or reading at a distance. An instrument scale, beginning at some point *OTHER THAN ZERO* is an advantage. Any of our standard DC instruments can be furnished with the zero suppressed. The suppression does *NOT* increase accuracy which remains exactly the same as before suppressing the scale. Excessive amounts of suppression will introduce difficulties with spring fatigue, which, while tolerable in low accuracy instruments, cannot be allowed in the usual accuracies associated with *SENSITIVE RESEARCH* instruments. In no case is more than 50% suppression acceptable in this class of instrument.

It is practically impossible to mention the above mechanically suppressed zero instruments without calling attention to the *SRIC INCREMETER* type of instrument in which suppressions of as much as 90% can be had and with accuracies increasing with the amount of electrical suppression used. Electrically suppressed instruments with 90% suppression have accuracies of .05%. (Copies of the November 1958 issue of *ELECTRICAL MEASUREMENTS* describes this instrument in detail. Back copies are available from us.)

THERMOCOUPLES AGAIN

We wish to repeat a warning about the use of thermocouples in circuits where there are any elements with storage capacity. Any circuit in which there is either a capacitor or an inductor, has potential storage of energy. In any circuit containing energy storage, care must be used to prevent either the charging or discharging currents from flowing through a thermocouple instrument. These transient currents may be *MANY TIMES* the steady state value and be of sufficient duration to cause thermocouple damage.

The best safeguard for these transient conditions is the use of a variable transformer (such as a *VARIAC*, etc.) instead of a switch, for turning "on and off" experimental circuits in which thermal instruments are used. We heartily recommend this precaution.

LONG LEAD MILLIVOLTMETER ERRORS

Many people in measuring *HIGH* DC currents, feel that the shunt can be placed anywhere and leads of any length run to the millivoltmeter. This is a dangerous assumption.

We have encountered cases where this has caused trouble from an easily forgotten source. The villain which is often unsuspected, is AC pickup from outside sources. Because of the low impedance of such circuits, appreciable current may flow due to a relatively small induced voltage. These currents may be partially rectified by slightly oxidized connections forming a copper oxide-copper rectifier of low efficiency. The millivoltmeter being a very sensitive instrument, is easily influenced by such partially rectified AC voltage. The cure of this trouble of course is very simple. Twisted leads will eliminate the AC pickup sufficiently in most cases. For the rare case where this is not sufficient, shielding can be employed. Do not automatically assume that because it is a DC circuit, that it is completely immune to any AC pickup.

RADAR:

Several instances have come to our attention recently in which radar has been the villain in the demise of worthy thermocouples. The old and often repeated story of — "But, boss, I didn't burn it out — it never went off the scale," has been updated. It now comes out even more weird. "Honest, boss, I never even took it off the shelf."

The thermocouple instrument is a brilliant and often misunderstood relative of the instrument business. It has capabilities which no other instrument can approach when it comes to frequency response. In addition, it has high sensitivity and true RMS response. These very special characteristics are exactly what gets an innocent thermocouple into trouble. Most thermocouple instruments have some distributed capacity in the wiring and of necessity, a certain amount of inductance. This will provide a complete resonant circuit at some extremely high frequency.

Now the stage is all set for our little tragedy. Lurking next door is the villain in the form of a radar set. Putting out very high powers in the ultra high frequency regions, the radar forms the perfect set up to bring trouble to the thermocouple instrument. The beam swings across the shelf where the instrument is stored. A very appreciable voltage is induced in the resonant circuit in the instrument and the current flow is enough to cause burn out. This is not as impossible as a first thought would make it seem. Present day radar sets, with high powers and narrow beam widths, can place an appreciable amount of power into even a partially resonant circuit at distances of a few hundred yards. This has happened in several cases in which thermocouple burnout has been proved to be from this source.

Of course it should also be realized that the same induced voltage which can in certain instances cause burn out can also cause reading errors when the induction is below burn out point. In using thermocouple instruments near radar or for that matter near any other source of RF energy, it is wise to make sure that this energy is not entering the measurement circuit and *ADDING* to the reading.

SPECIAL INSTRUMENT ORDERS

In our general catalog the instrument ranges listed for various types of instruments represent the reasonable engineering limits within which that particular type of instrument can be readily built. We list the *MOST* sensitive and the *LEAST* sensitive which can be built with full expected quality. If your requirements are for a special instrument *WITHIN THESE LIMITS*, calling for odd value ranges, different scale or any other similar change, it is very easy to comply with this *SPECIAL* need. Mention the nearest standard instrument with the detailed modification you require.

When instruments *BEYOND* the ranges listed in the catalog are requested, it is of much greater importance to carefully spell out *all* of the requirements. It is almost certainly going to be necessary to sacrifice some of the normal characteristics, resistance, accuracy, speed of operation or scale length in order to extend them beyond listed ranges. Please use extra care in making such inquiries in the first letter.

It will save both of us time and effort.

Our general instrument catalog is yours for the asking from us or from our country and world wide representatives. Write to us directly or to any of our representatives.

INTERMEDIATE STANDARDS:

One factor that often seems to be overlooked in standardization programs is the proper use of *INTERMEDIATE STANDARDS* between the *BEST* precision *COMPANY* standards, and the working instrument in the plant. Regardless of the accuracy levels involved, it is a very good practice to use your *BEST STANDARDS* to calibrate a transfer instrument and to then take this instrument out into the plant for the calibration of the working equipment. This procedure accomplishes several things at once, all of which are desirable. It takes an appreciable working load off the best *STANDARDS* and hence prolongs their useful life and accuracy greatly. A first class standard usually cannot remain a precise *STANDARD* when used continuously as a working istrument. By calibrating one intermediate instrument and using it for the calibration of many working instruments before taking it back to the *STANDARD* for a recheck, keeps the precision *STANDARDS*, and possibly the personnel as well, in shape for the high accuracy work for which they are really needed.

In addition, the calibration of working instruments "in position" is recommended, rather than the risk of transportation to the calibration laboratory of the working instruments. Our Model C (DC) and Model D (AC) *REFERENCE STANDARD* instruments are much used for this purpose and are remarkably well suited to such uses because of their rugged portable construction combined with excellent accuracy and stability.

NOTE! Where extreme calibration accuracy is necessary *AT CERTAIN PLANT POSITIONS*, our new *CALIBRATION CONSOLES* are available. They can be furnished mounted on movable carts. These consoles have accuracies of .05% of any reading.

INSTRUMENT STORAGE

The problem of long term instrument storage is simple, but often neglected. If an electrical indicating instrument is to be stored for long periods of time a few special precautions should be taken. For protection against moisture it should be placed in a relatively well sealed container. Plastic bags make satisfactory containers. Inside the container with the instrument should be a few ounces of silica gel or similar dessicant. The case should then be packed into a cushioned container, the amount of cushioning depending on the storage conditions and shock or vibration which may be encountered. When the instrument is finally placed in storage it should be laid in such a position that it is *upside down* from its normal reading position. This upside down position will prevent damage to the bottom pivot of the instrument, should it receive a greater than tolerable shock. Slight damage to the top pivot of an instrument will have far less effect on the operation than the same amount to lower pivot, and so is the lesser of two evils.

The plastic bag and the storage in an upside down position are desirable precautions for long term storage, even on laboratory shelves.

All the above suggestions also are applicable to packing for shipment, except for the need of silica gel. In normal shipping, the instrument in its plastic bag is packed in at least two inches of cushioned packing and placed in a cardboard container. This container in turn should be placed in a second container with at least a similar two inches of cushioned packing. This amount of packing is sufficient for the usual five or six inch scale portable instrument. For instruments of the laboratory standard size and weight, the thickness of cushioning should be at least doubled. There are many types of suitable cushioning material. Our own experience has been most satisfactory with the rubberized hair type of material.

PLEASE HELP

There comes a time in the life of almost every instrument when it has to be repaired. At this crucial time, you, the customer, can do us a very great favor and at the same time help yourselves. If you will pack the instrument as described above, it will help the instrument to arrive in no worse condition than it already is in. When the instrument arrives here, it will save a great deal of repair time if we know just what the difficulty is before we start work on it. Give as complete a description of the difficulty as possible. If the instrument has a "sticky" action, tell us at what part of the scale it sticks. If it is off calibration, at what point, and how much, will help us pin point the difficulty quicker. We give the instrument a complete checkout before it is returned to you in any case, but it will save a great deal of time and reduce your repair cost if we do not have to go through this entire checkout procedure *IN THE BEGINNING*, to find out the difficulty and then do it all over again after the instrument is repaired.

This call for your help is particularly needed in the case of intermittent types of trouble. Be as specific as possible in this case, because by the very contrary nature of such troubles, they will not show up here at the laboratory until we have spent a lot of time futilely checking it out. In some cases the instrument might even be returned to you without finding the difficulty because some other small error was located, corrected, and assumed to be the main difficulty.

WE ARE INTERESTED IN YOUR PROBLEMS!

We consider ourselves to be fairly well versed instrument engineers, and reasonably well informed on general instrumentation practice. The only way we maintain this status is by a steady and consistent reviewing of the field. We are interested in your measurement problems and are willing to pass on any information that we may have on any measurement subject. Conversely, we are always very willing and anxious to hear from you of unique solutions to such problems.

If you successfully solve any unusual or otherwise difficult measurement job, especially if it involves one of our instruments, we will be very glad to hear about it. When you let us know about it, if possible, could you give us permission to publicize it in these *"POTPOURRI"* issues.

If you merely have the problem, without the solution, it may still be worth your while to let us know about it. There are probably a great number of special type instruments that we could make for you with very little effort, if we knew just what you needed.

COMPENSATED WATTMETER CIRCUIT

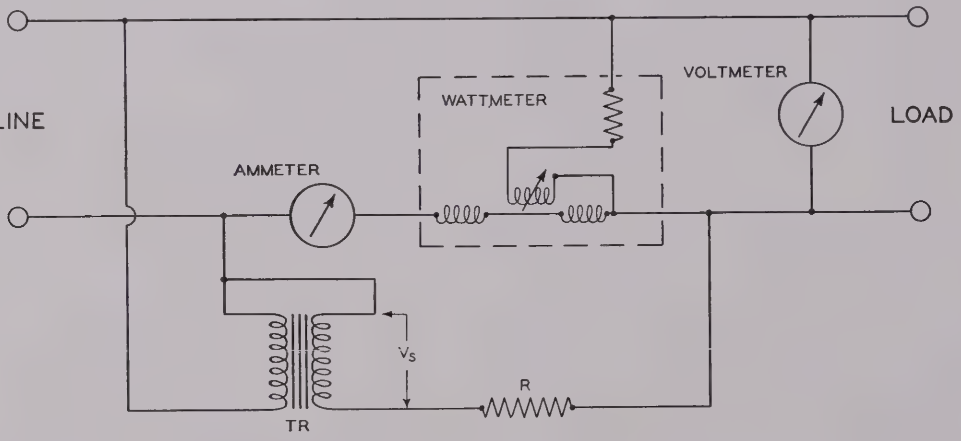
Wattmeter instruments of the dynamometer type have one error that is inherent in the design of the instrument. They *ALWAYS* read the power being consumed in the load *PLUS* the power required to drive the wattmeter itself. In fairly high power instruments, the addition of the wattmeter losses is a total negligible error. But at low and medium power measurements, the "tare" in the readings cannot be neglected. Compensation when built into the instrument always tends to make a poorer instrument because of the space reductions in the main field coils required by the compensation fields.

The circuit shown below will allow a standard wattmeter to give "tare-free" readings and eliminate the effect of the potential circuit losses, also of the external voltmeter current, from *BOTH* the wattmeter and ammeter readings. The wattmeter is connected in the usual manner in which it will read the load power, *PLUS* its own potential circuit power, *PLUS* the power consumed in the voltmeter. Transformer TR is a good quality unit designed with the primary able to handle the expected range of line voltages involved. The secondary of TR feeds a circuit composed of the resistance R, the field coils of the wattmeter and the ammeter. The secondary must supply a current *EQUAL* to the combined currents of the voltmeter and the wattmeter potential circuit. Resistance R must be large by comparison to the impedance of the ammeter and field coils of the wattmeter.

Resistance (R) is adjusted to produce a current *EQUAL AND OPPOSITE* to that drawn by the potential circuits. This is easily accomplished by momentarily open circuiting the load terminals and adjusting R for zero deflection of the wattmeter and the current meter. If no zero balance can be obtained, the secondary voltage (V_S) is undoubtedly in phase with the load current and either the primary or secondary terminals of the transformer TR should be reversed.

For temporary laboratory set-ups the resistance R can be a rheostat or decade box and be readily adjusted for the individual reading. However, the resistance R will be constant for any given voltmeter and wattmeter range setting regardless of the point on the scale being read. R will have to be changed only when the range of either the wattmeter potential circuit or the voltmeter is changed. In fact R can be a complex resistor network operating with the range switch of the instruments and make all readings of the wattmeter and current meter (true net) readings. This is the basic system used in the *SENSITIVE RESEARCH MAGNETIC TEST SET AND CORE LOSS TEST SETS*, to give watt readings which do not have to have power loss corrections.

The exact values of (R) and (V_S) are not critical except as specified above and most wattmeter set-ups can be compensated with regular commercial power transformers available from the nearest radio distributor.



YOUR MAIL WILL BRING YOU, WITHIN A SHORT TIME, ANOTHER ISSUE OF

"ELECTRICAL MEASUREMENTS"

IN THIS ISSUE, WE DESCRIBE A COMPLETE LINE OF

STANDARDIZING TEST CONSOLES

with an accuracy of

.05 of 1% of any reading (AC or DC)

PLEASE WATCH FOR IT.

For the past 31 years we have published this company bulletin "ELECTRICAL MEASUREMENTS." In it we describe new and unusual instruments and measurement techniques. It is mailed without cost to interested persons. If you have not been receiving this interesting publication, please advise.

SRICO,

Sens

Electrical MEASUREMENTS

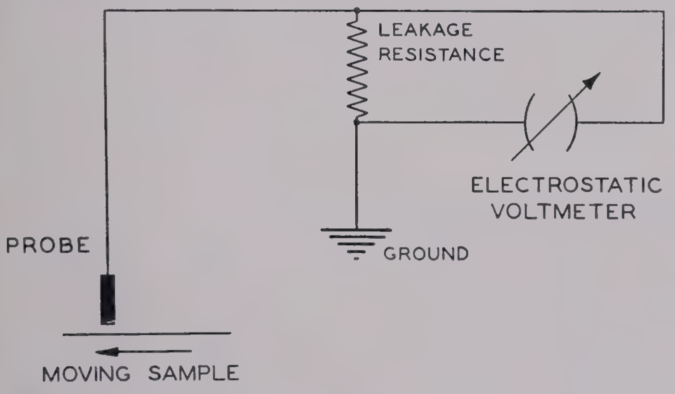
VOLUME 27 DECEMBER 1959 NUMBER 12

"POTPOURRI II"

Last December, we issued our first *"POTPOURRI"* in which we described a few of the problems and items of interest that continually pass across the desks of our Engineering Department. That issue of *ELECTRICAL MEASUREMENTS* was so well received, that *"POTPOURRI II"* has become necessary.

MORE ABOUT ELECTROSTATIC VOLTMETERS

Several people have lately come up with difficulties in measuring electrostatically developed voltages by means of our electrostatic voltmeters. One of the common complaints is, "I use a well insulated probe near a moving paper strip, plastic film, or similar static offender and the electrostatic voltmeter merely goes up scale and stays there even when I know the static is varying.



WHY? The answer is simple. The electrostatic instrument is extremely well insulated and if the probe is equally well insulated, there is no path for the *CHARGE OF THE INSTRUMENT* to leak off, and hence the pointer just sits up there at the peak voltage and stays put. The cure is equally simple. Shunt a very high value resistance across the instrument until the time constant is sufficiently low to allow the instrument to follow expected variations of the static charge. This resistor will reduce sensitivity but a satisfactory compromise "sensitivity" vs. "response" can usually be reached.

The second question asked many, many times is, "My probe works fine on the continuously running sheet, but when I try to investigate small variations on the stopped sheet, or the charge on a fixed solid, or any single charge phenomenon, I get no reaction even though I know there is a charge there.

Again, *"WHY?"* In this case the answer is only obvious after it is called to your attention. The electrostatic voltmeter can be considered as a perfect voltmeter in parallel with a capacitor. The voltmeter requires no energy but it *DOES* require energy to build up a charge on the capacitor.

If a probe touches one small spot on the surface of a charged body it can collect charge from only the very small area which it actually contacts. The suface is an insulator and charge from other portions of the surface cannot flow in to replace that at the contacted surface. In the case of the moving surface, the probe scans a large area as the surface moves below it and thus gives the effect of a very much larger area. The answer is to use a *LARGER PROBE AREA* for stationary measurements. When the probe area is sufficient to have a surface capacity equal to the capacitance of the instrument, then the charge on the surface contacted will divide equally between the probe and the instrument, and a reading of exactly one half the voltage present before the probe was placed will appear on the instrument.

VPA UNITS:

The SRIC Peak Voltage units (Type VPA) are a simple way to adapt our Model ESD or ESH electrostatic voltmeters to read peak voltages. In using these units it must be remembered that the VPA unit is a peak rectifier unit and that it delivers a DC voltage to the electrostatic instrument used with it for measurements of peak voltages. Because the instrument *SEES ONLY* a DC voltage regardless of the AC which may be applied to the VPA, only the lowest range of multirange ESD instruments are suitable for use with these units. The ranges, other than the lowest on this model ESD voltmeter, are obtained by means of capacity dividers and will give accurate readings only on AC voltages. Hence they should not be used with VPA units, (Additional information on these units available from us if desired.) Model ESH electrostatic voltmeters *DO NOT* have this limitation.

SENSITIVE RESEARCH INSTRUMENT CORPORATION
NEW ROCHELLE, N. Y.
ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927
S
Symbol of Quality

SUPPRESSED ZERO INSTRUMENTS:

In some instances extra readability in an instrument scale may be needed for either faster reading or reading at a distance. An instrument scale, beginning at some point *OTHER THAN ZERO* is an advantage. Any of our standard DC instruments can be furnished with the zero suppressed. The suppression does *NOT* increase accuracy which remains exactly the same as before suppressing the scale. Excessive amounts of suppression will introduce difficulties with spring fatigue, which, while tolerable in low accuracy instruments, cannot be allowed in the usual accuracies associated with *SENSITIVE RESEARCH* instruments. In no case is more than 50% suppression acceptable in this class of instrument.

It is practically impossible to mention the above mechanically suppressed zero instruments without calling attention to the *SRIC INCREMETER* type of instrument in which suppressions of as much as 90% can be had and with accuracies increasing with the amount of electrical suppression used. Electrically suppressed instruments with 90% suppression have accuracies of .05%. (Copies of the November 1958 issue of *ELECTRICAL MEASUREMENTS* describes this instrument in detail. Back copies are available from us.)

THERMOCOUPLES AGAIN

We wish to repeat a warning about the use of thermocouples in circuits where there are any elements with storage capacity. Any circuit in which there is either a capacitor or an inductor, has potential storage of energy. In any circuit containing energy storage, care must be used to prevent either the charging or discharging currents from flowing through a thermocouple instrument. These transient currents may be *MANY TIMES* the steady state value and be of sufficient duration to cause thermocouple damage.

The best safeguard for these transient conditions is the use of a variable transformer (such as a *VARIAC*, etc.) instead of a switch, for turning "on and off" experimental circuits in which thermal instruments are used. We heartily recommend this precaution.

LONG LEAD MILLIVOLTMETER ERRORS

Many people in measuring *HIGH* DC currents, feel that the shunt can be placed anywhere and leads of any length run to the millivoltmeter. This is a dangerous assumption.

We have encountered cases where this has caused trouble from an easily forgotten source. The villain which is often unsuspected, is AC pickup from outside sources. Because of the low impedance of such circuits, appreciable current may flow due to a relatively small induced voltage. These currents may be partially rectified by slightly oxidized connections forming a copper oxide-copper rectifier of low efficiency. The millivoltmeter being a very sensitive instrument, is easily influenced by such partially rectified AC voltage. The cure of this trouble of course is very simple. Twisted leads will eliminate the AC pickup sufficiently in most cases. For the rare case where this is not sufficient, shielding can be employed. Do not automatically assume that because it is a DC circuit, that it is completely immune to any AC pickup.

RADAR:

Several instances have come to our attention recently in which radar has been the villain in the demise of worthy thermocouples. The old and often repeated story of — "But, boss, I didn't burn it out — it never went off the scale," has been updated. It now comes out even more weird. "Honest, boss, I never even took it off the shelf."

The thermocouple instrument is a brilliant and often misunderstood relative of the instrument business. It has capabilities which no other instrument can approach when it comes to frequency response. In addition, it has high sensitivity and true RMS response. These very special characteristics are exactly what gets an innocent thermocouple into trouble. Most thermocouple instruments have some distributed capacity in the wiring and of necessity, a certain amount of inductance. This will provide a complete resonant circuit at some extremely high frequency.

Now the stage is all set for our little tragedy. Lurking next door is the villain in the form of a radar set. Putting out very high powers in the ultra high frequency regions, the radar forms the perfect set up to bring trouble to the thermocouple instrument. The beam swings across the shelf where the instrument is stored. A very appreciable voltage is induced in the resonant circuit in the instrument and the current flow is enough to cause burn out. This is not as impossible as a first thought would make it seem. Present day radar sets, with high powers and narrow beam widths, can place an appreciable amount of power into even a partially resonant circuit at distances of a few hundred yards. This has happened in several cases in which thermocouple burnout has been proved to be from this source.

Of course it should also be realized that the same induced voltage which can in certain instances cause burn out can also cause reading errors when the induction is below burn out point. In using thermocouple instruments near radar or for that matter near any other source of RF energy, it is wise to make sure that this energy is not entering the measurement circuit and *ADDING* to the reading.

SPECIAL INSTRUMENT ORDERS

In our general catalog the instrument ranges listed for various types of instruments represent the reasonable engineering limits within which that particular type of instrument can be readily built. We list the *MOST* sensitive and the *LEAST* sensitive which can be built with full expected quality. If your requirements are for a special instrument *WITHIN THESE LIMITS*, calling for odd value ranges, different scale or any other similar change, it is very easy to comply with this *SPECIAL* need. Mention the nearest standard instrument with the detailed modification you require.

When instruments *BEYOND* the ranges listed in the catalog are requested, it is of much greater importance to carefully spell out *all* of the requirements. It is almost certainly going to be necessary to sacrifice some of the normal characteristics, resistance, accuracy, speed of operation or scale length in order to extend them beyond listed ranges. Please use extra care in making such inquiries in the first letter.

It will save both of us time and effort.

Our general instrument catalog is yours for the asking from us or from our country and world wide representatives. Write to us directly or to any of our representatives.

INTERMEDIATE STANDARDS:

One factor that often seems to be overlooked in standardization programs is the proper use of *INTERMEDIATE STANDARDS* between the *BEST* precision *COMPANY* standards, and the working instrument in the plant. Regardless of the accuracy levels involved, it is a very good practice to use your *BEST STANDARDS* to calibrate a transfer instrument and to then take this instrument out into the plant for the calibration of the working equipment. This procedure accomplishes several things at once, all of which are desirable. It takes an appreciable working load off the best *STANDARDS* and hence prolongs their useful life and accuracy greatly. A first class standard usually cannot remain a precise *STANDARD* when used continuously as a working istrument. By calibrating one intermediate instrument and using it for the calibration of many working instruments before taking it back to the *STANDARD* for a recheck, keeps the precision *STANDARDS*, and possibly the personnel as well, in shape for the high accuracy work for which they are really needed.

In addition, the calibration of working instruments "in position" is recommended, rather than the risk of transportation to the calibration laboratory of the working instruments. Our Model C (DC) and Model D (AC) *REFERENCE STANDARD* instruments are much used for this purpose and are remarkably well suited to such uses because of their rugged portable construction combined with excellent accuracy and stability.

NOTE! Where extreme calibration accuracy is necessary *AT CERTAIN PLANT POSITIONS*, our new *CALIBRATION CONSOLES* are available. They can be furnished mounted on movable carts. These consoles have accuracies of .05% of any reading.

INSTRUMENT STORAGE

The problem of long term instrument storage is simple, but often neglected. If an electrical indicating instrument is to be stored for long periods of time a few special precautions should be taken. For protection against moisture it should be placed in a relatively well sealed container. Plastic bags make satisfactory containers. Inside the container with the instrument should be a few ounces of silica gel or similar dessicant. The case should then be packed into a cushioned container, the amount of cushioning depending on the storage conditions and shock or vibration which may be encountered. When the instrument is finally placed in storage it should be laid in such a position that it is *upside down* from its normal reading position. This upside down position will prevent damage to the bottom pivot of the instrument, should it receive a greater than tolerable shock. Slight damage to the top pivot of an instrument will have far less effect on the operation than the same amount to lower pivot, and so is the lesser of two evils.

The plastic bag and the storage in an upside down position are desirable precautions for long term storage, even on laboratory shelves.

All the above suggestions also are applicable to packing for shipment, except for the need of silica gel. In normal shipping, the instrument in its plastic bag is packed in at least two inches of cushioned packing and placed in a cardboard container. This container in turn should be placed in a second container with at least a similar two inches of cushioned packing. This amount of packing is sufficient for the usual five or six inch scale portable instrument. For instruments of the laboratory standard size and weight, the thickness of cushioning should be at least doubled. There are many types of suitable cushioning material. Our own experience has been most satisfactory with the rubberized hair type of material.

PLEASE HELP

There comes a time in the life of almost every instrument when it has to be repaired. At this crucial time, you, the customer, can do us a very great favor and at the same time help yourselves. If you will pack the instrument as described above, it will help the instrument to arrive in no worse condition than it already is in. When the instrument arrives here, it will save a great deal of repair time if we know just what the difficulty is before we start work on it. Give as complete a description of the difficulty as possible. If the instrument has a "sticky" action, tell us at what part of the scale it sticks. If it is off calibration, at what point, and how much, will help us pin point the difficulty quicker. We give the instrument a complete checkout before it is returned to you in any case, but it will save a great deal of time and reduce your repair cost if we do not have to go through this entire checkout procedure *IN THE BEGINNING*, to find out the difficulty and then do it all over again after the instrument is repaired.

This call for your help is particularly needed in the case of intermittent types of trouble. Be as specific as possible in this case, because by the very contrary nature of such troubles, they will not show up here at the laboratory until we have spent a lot of time futilely checking it out. In some cases the instrument might even be returned to you without finding the difficulty because some other small error was located, corrected, and assumed to be the main difficulty.

WE ARE INTERESTED IN YOUR PROBLEMS!

We consider ourselves to be fairly well versed instrument engineers, and reasonably well informed on general instrumentation practice. The only way we maintain this status is by a steady and consistent reviewing of the field. We are interested in your measurement problems and are willing to pass on any information that we may have on any measurement subject. Conversely, we are always very willing and anxious to hear from you of unique solutions to such problems.

If you successfully solve any unusual or otherwise difficult measurement job, especially if it involves one of our instruments, we will be very glad to hear about it. When you let us know about it, if possible, could you give us permission to publicize it in these *"POTPOURRI"* issues.

If you merely have the problem, without the solution, it may still be worth your while to let us know about it. There are probably a great number of special type instruments that we could make for you with very little effort, if we knew just what you needed.

COMPENSATED WATTMETER CIRCUIT

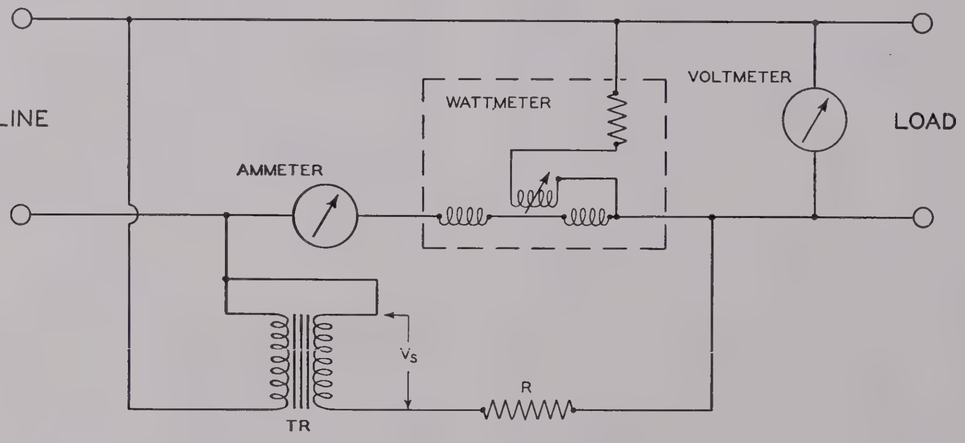
Wattmeter instruments of the dynamometer type have one error that is inherent in the design of the instrument. They *ALWAYS* read the power being consumed in the load *PLUS* the power required to drive the wattmeter itself. In fairly high power instruments, the addition of the wattmeter losses is a total negligible error. But at low and medium power measurements, the "tare" in the readings cannot be neglected. Compensation when built into the instrument always tends to make a poorer instrument because of the space reductions in the main field coils required by the compensation fields.

The circuit shown below will allow a standard wattmeter to give "tare-free" readings and eliminate the effect of the potential circuit losses, also of the external voltmeter current, from *BOTH* the wattmeter and ammeter readings. The wattmeter is connected in the usual manner in which it will read the load power, *PLUS* its own potential circuit power, *PLUS* the power consumed in the voltmeter. Transformer TR is a good quality unit designed with the primary able to handle the expected range of line voltages involved. The secondary of TR feeds a circuit composed of the resistance R, the field coils of the wattmeter and the ammeter. The secondary must supply a current *EQUAL* to the combined currents of the voltmeter and the wattmeter potential circuit. Resistance R must be large by comparison to the impedance of the ammeter and field coils of the wattmeter.

Resistance (R) is adjusted to produce a current *EQUAL AND OPPOSITE* to that drawn by the potential circuits. This is easily accomplished by momentarily open circuiting the load terminals and adjusting R for zero deflection of the wattmeter and the current meter. If no zero balance can be obtained, the secondary voltage (V_S) is undoubtedly in phase with the load current and either the primary or secondary terminals of the transformer TR should be reversed.

For temporary laboratory set-ups the resistance R can be a rheostat or decade box and be readily adjusted for the individual reading. However, the resistance R will be constant for any given voltmeter and wattmeter range setting regardless of the point on the scale being read. R will have to be changed only when the range of either the wattmeter potential circuit or the voltmeter is changed. In fact R can be a complex resistor network operating with the range switch of the instruments and make all readings of the wattmeter and current meter (true net) readings. This is the basic system used in the *SENSITIVE RESEARCH MAGNETIC TEST SET AND CORE LOSS TEST SETS*, to give watt readings which do not have to have power loss corrections.

The exact values of (R) and (V_S) are not critical except as specified above and most wattmeter set-ups can be compensated with regular commercial power transformers available from the nearest radio distributor.



YOUR MAIL WILL BRING YOU, WITHIN A SHORT TIME, ANOTHER ISSUE OF

"ELECTRICAL MEASUREMENTS"

IN THIS ISSUE, WE DESCRIBE A COMPLETE LINE OF

STANDARDIZING TEST CONSOLES

with an accuracy of

.05 of 1% of any reading (AC or DC)

PLEASE WATCH FOR IT.

For the past 31 years we have published this company bulletin "ELECTRICAL MEASUREMENTS." In it we describe new and unusual instruments and measurement techniques. It is mailed without cost to interested persons. If you have not been receiving this interesting publication, please advise.

SRICO,

Electrical MEASUREMENTS

VOLUME 27 NOVEMBER 1958 NUMBER 11

JAN 1 1959 PM

DIRECT CURRENT

DIFFERENTIAL "63" INCREMETER

MODEL INCRE

New!

DIFFERENTIAL "63" INCREMETER
MILLIAMPERES
VOLTS
10 20 30 40 50 60 70 80 90 100

PORTABLE
OR
PANEL MOUNTED

ACCURACY
.05 OF 1%

EFFECTIVE SCALE LENGTH, 63 inches
EFFECTIVE SCALE DIVISIONS — 1000

This new DIFFERENTIAL INCREMETER is a unique combination of the very old and the completely new in instrumentation. Differential instruments have been used for high accuracy comparisons for many years. Now, due to extensive development work at SENSITIVE RESEARCH we have combined differential instrument "High *COMPARATIVE* Accuracy" with a "HIGHLY Accurate" stable reference source and produced a 63 inch scale instrument with .05% accuracy. The DIFFERENTIAL INCREMETER has a 6.3 inch scale.

The addition of an expansion circuit allows this 6.3 inch scale to be effectively spread out to ten times its own length. This is accomplished by making it read in successive positions, zero to .1 full scale, .1 to .2 of full scale, .3 to .4 of full scale, etc. This enables an instrument "readability" never before attained in direct indicating instruments. It creates a 63 inch, ONE THOUSAND division scale, with an absolute accuracy of one-half division and stability and readability of a small fraction of this half division.

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

S

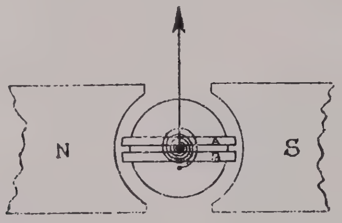
Symbol of Quality

DIFFERENTIAL "63" INCREMETER

ACCURACY .05 OF 1%

The torque producing mechanism of the well-known moving coil, permanent magnet type of instrument is an efficient device. The current through the moving coil which is sufficient to drive the pointer to full scale is relatively small in comparison to the maximum current carrying capacity of the wire used. Current of MANY TIMES the full scale current can be sent through the moving coil without causing overheating of the coil and consequent loss of accuracy. These higher currents must be applied slowly or the movement must be heavily damped to prevent mechanical damage as the pointer attempts to move to a position many times past full scale. This mechanical protection can be easily accomplished by means of eddy current damping.

The above "FACTS OF LIFE" for DC movements are exploited in the differential moving coil system shown in figure #1.



①

In this system there are two electrically independent coils wound on the same moving assembly. It is obvious that either of these coils can be used by itself to operate the pointer in a perfectly normal manner. When the two coils are supplied with current simultaneously and with the same polarity the torques produced by the respective currents will ADD and produce a deflection proportional to the SUM of the two currents. If, however, the two currents are supplied with OPPOSITE POLARITIES the net torque will be proportional to the DIFFERENCE of the two currents. When these two currents are equal to each other the net torque is ZERO regardless of their magnitude. Let us assume that we make a movement with a zero center pointer and with coils such that either one by itself will swing the pointer to full scale (left or right) for 50 milliamperes. If we further assume a 100 division scale marked 50 - 0 - 50, we have a complete and useful instrument. This movement can now be supplied with 49 milliamperes in one coil and 50 milliamperes in the other coil. The net torque of these two currents if they are of opposite polarity will be sufficient to cause a 1 division deflection in the direction of the larger current. If we know the 50 milliamperes to be accurate, we then know that the smaller current is 49 milliamperes (50 - 1). Our comparison sensitivity is 1 division. This is a 2% difference between the currents (1 div. in 50 equals 2%).

It is possible to take advantage of the inherent overload of the differential moving coil system as brought out in paragraph one. Instead of 49 and 50 milliamperes we can use currents of 499 and 500 milliamperes without in any way damaging the coils. A deflection will be obtained of one division, the same as before, because the difference is still 1 milliampere (500-499). However our comparison sensitivity is now 1 division in 500, or .2%, a gain in comparison sensitivity of 10 times, the exact factor by which we were able to run excess current through the movement. This basic increase in comparison sensitivity by making use of the overload characteristics of such moving coil systems has been recognized for many years. The only drawback to the realization of greater accuracy by use of differential instruments was in the obtaining of a satisfactory reference current to supply one of the two currents in order to change the HIGH COMPARATIVE accuracy into a HIGH ABSOLUTE ACCURACY. This ordinarily required a standard cell and galvanometer and constant rechecking and adjustment in order to maintain a satisfactory reference.

New "SENSITIVE RESEARCH" engineering advances in the design of miniature high stability power supplies have been used by us to produce a compact "BLACK BOX" reference source with very unusual characteristics. Using regulation—on regulation—on regulation techniques we have designed a compact supply capable of furnishing 1 milliampere D.C. reference currents from a 60 cycle line that are phenomenally stable. Within the limits of line voltage variations from 90 to 135 volts and ambient temperature variations of 10 to 40 degrees Centigrade, these supplies will furnish a reference 1 milliampere with a stability of appreciably better than .01% and with a design life expectancy in excess of 25,000 hours.

In figure #2 a typical differential movement is combined with our design stable reference source to provide an extremely high accuracy DC instrument with a wide range of measurement and several unique features. The basic differential movement in this case has a sensitivity of 0 to 100 microamperes in each section. If the instrument is used on the most sensitive current range (0 to 1 milliampere) and the switch on the reference half of the instrument is set at 0 - .1, there is no reference current supplied, and the instrument will deflect full scale for 100 microamperes (.1 of 1 milliampere). If the suppresion switch is now turned to the .1 - .2 position, a portion of the reference current is fed into the other half of the instrument moving coil system. Actually 100 microamperes is now flowing in the reference half and it would take 100 microamperes from the external source merely to bring the pointer to zero, therefore 200 microamperes will be required for full scale deflection. In other words the scale now reads not 0 to .1 milliamperes but .1 to .2 milliamperes. Similarly as we rotate the suppression switch we put greater currents through the reference half of the differential moving coil system and the scale reads progressively .2 to .3 ma., .3 to .4 ma., etc., up until with 900 microamperes flowing in the reference circuit, the scale reading is 0 to .1 milliampere. In effect we have "expanded" each tenth of the normal 0 to 1 milliampere scale of 6.3 inches into a full scale deflection of its own for a total effective scale length of 63 inches.

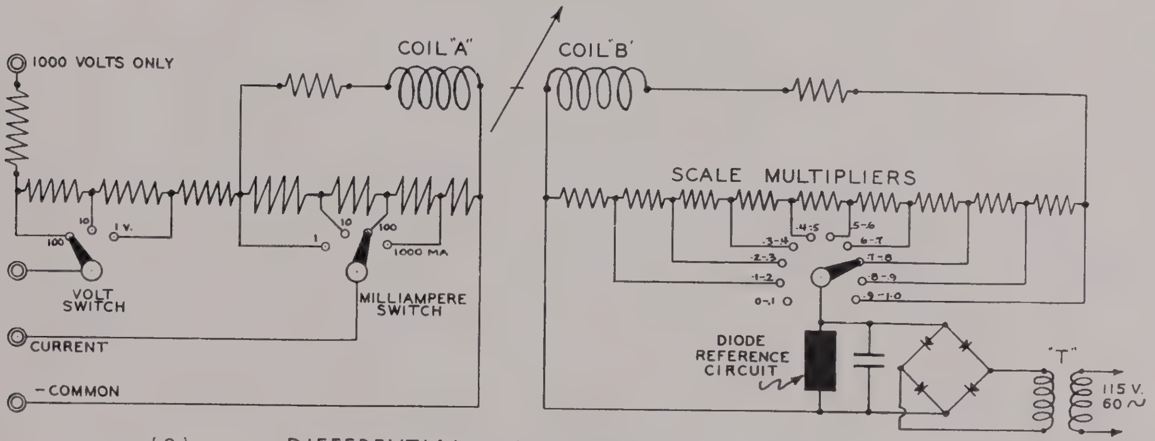
The accuracy of such a radically different type of instrument must be very carefully stated and understood for the completely satisfactory usage of this new instrument.

For any given range there are ten different sets of scale readings obtainable from 0 - .1 to .9 - 1.0 of the particular range involved. The accuracy is stated in terms of the FULL SCALE value of THE RANGE IN USE, regardless of what particular small section of that range the scale may be reading at the moment. This means that the 1 volt range which is spread over 63 inches of total scale length with 1000 scale divisions has an accuracy of .05% of full scale (.05% of 1 volt) which is ± .5 millivolt. This is true regardless of whether the scale is reading 0 - .1 volt, .2 - .3 volt or .9 - 1.0 volt at the moment. The accuracy is stated in terms of the full range in use without regard to the section which may be expanded at the time.

Accuracies are always stated in terms of Absolute values of current and/or voltage applied. In this particular type of instrument the resolution and repeatability of the readings are very markedly in excess of the absolute accuracy which can be guaranteed. Readings can easily be made to a resolution of .02% as this requires only the estimation of fifths of a division.

The repeatability of readings is even better than this, being in the order of .01%. These are phenomenal values of instrument readability and stability, never before achieved with direct reading instruments. These previously unheard of accuracies pose problems in the actual calibration of such instruments. For instance, in calibrating with the well known BROOKS POTENTIOMETER, (a widely used instrument in instrument standardizing laboratories) the pointer movement of the DIFFERENTIAL 63 INCREMETER is greater than the galvanometer pointer movement on the potentiometer. Many of the instrument's internal resistors must be adjusted using the instrument as its OWN INDICATOR because the instrument will show .01% variations quite readily which the usual bridges do not indicate. The very high readability of these instruments, (.1% is a full division) shows up power supply variations and similar slight variables that are ordinarily not noticed. In fact, until the user becomes familiar with this tremendous scale expansion it is very surprising to find that things are not quite as stable as believed.

We welcome suggestions from you — our customer friends — on possible applications of this new unusual measuring instrument development.



(2) DIFFERENTIAL INCREMETER CIRCUIT

ACCURACY .05 OF 1%

The accuracy is stated in terms of full scale of the range being used and is ± .05% of this value regardless of the scale expansion factor in use.

Over the total range spread of 0 - 1 MA. (0 - .1, .1 - .2 . . . .9 - 1.0) the accuracy is ± .5 microampere The range spreads are as shown below:

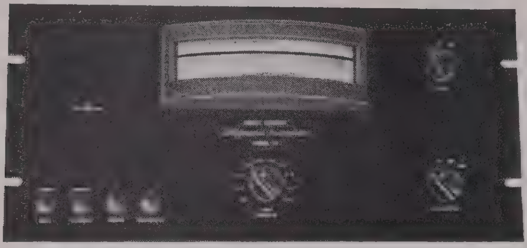
0 - 1	Ma. range spread is ± .5 Microampere		0 - 1	Volt range spread is ± .5 Millivolt
0 - 10	Ma. range spread is ± 5 Microamperes		0 - 10	Volt range spread is ± 5 Millivolts
0 - 100	Ma. range spread is ± 50 Microamperes		0 - 100	Volt range spread is ± 50 Millivolts
0 - 1000	Ma. range spread is ± .5 Milliampere		0 - 1000	Volt range spread is ± .5 Volt

The above accuracies apply for all positions of the range expansion switch. For example: 850 microamperes reads on the 1 ma. range with the expansion switch at .8 - .9 with an accuracy of ± .5 microampere.

Ranges	Code Word	Effective Scale Divisions	Price
1/10/100/1000 Volts (1000 ohms per volt) 1/10/100/1000 Milliamperes	SUPRES	1000	$860.00

(Total effective scale length, 63 inches)

Rack mounted "Incremeters" available — (see next page)



Size — 19" x 8¾"
Depth behind panel — 5 inches
in Black Bakelite or Gray Finished Aluminum

PANEL MOUNTED D.C. DIFFERENTIAL "70" INCREMETER

Using our Edgewise reading panel instrument with its seven (7") inch scale length we have available an instrument with an effective 70" scale length.

All connections are available at binding posts on the front panel and on terminals in the rear for permanent wiring. The ranges are identical with that of the portable "63" Incremeter.

MODEL INCRE

ELECTRICALLY SUPPRESSED ZERO D.C. INSTRUMENTS

PORTABLE OR PANEL MOUNTED

PORTABLE CASE — 13¾" x 7½" x 8¼"

Using our new high stability power supply controlled by an almost unbelievably accurate diode reference circuit, we now have available a series of ELECTRICALLY SUPPRESSED ZERO instruments. Such instruments are markedly different and superior to any other suppressed zero, narrow range instruments.

The greater the electrical suppression, the greater the accuracy with this type of instrument, and suppressions of up to 90% are completely satisfactory and will allow accuracies of .05%.

The suppression current is obtained from the 115 volt 60 cycle line (available for 50 cycle on special order) and is regulated within .01% for line voltage variation between 90 and 130 volts and for a temperature range of 10 deg. C to 40 deg. C.

PANEL SIZE — See photo above

These instruments are extremely easy to use. Simply turn on power (115 volts, 60 cycles) and use. Power consumption from line is only 25 va.

This "NEW" SENSITIVE RESEARCH type of ELECTRICALLY SUPPRESSED ZERO instrument can be furnished in any range of current of 200 microamperes or more and any range of voltage of 200 millivolts or more and with any degree of expansion up to 90%. By 90% expansion is meant that for whatever the range of the instrument is only the portion from 90% to 100% appears on the scale and all values below 90% of full scale will be below the lowest scale marking, i.e.: off scale to the left in the usual instrument. Accuracies obtained will be as follows: 50% suppression gives .25% accuracy—80% suppression gives .1% accuracy and 90% suppression (the maximum allowable suppression) will give an accuracy of .05%. All accuracy values are given in terms of percentage of full scale.

POPULAR RANGES OF ELECTRICALLY SUPPRESSED ZERO DIRECT CURRENT VOLTMETERS

Ranges listed below are only samples of what can be furnished. The purchaser can select any range or ranges desired to fit the requirements of his application — as long as they are within the minimum specifications listed for the incremeter.

Full Scale Volts	Scale Length	Effective Scale Length	Accuracy % of Full Scale	Code Word	Price
6 - 7	7"	7"	.075%	SUPVOL	$464.00
6 - 8	7"	7"	.10 %	SUPVOM	464.00
12 - 14	7"	7"	.075%	SUPVOT	464.00
24 - 28	7"	7"	.075%	SUPVOK	464.00
110 - 120	7"	7"	.05 %	SUPVOY	464.00

Voltmeters available down to .2 volt full scale. Correspondence solicited.

MULTIRANGE D.C. VOLTMETERS

6 - 7 / 12 - 14 / 24 - 28	7"	21"	.075%	SUPMOB	$534.00
100 - 110 / 110 - 120 / 120 - 130	7"	21"	.05 %	SUPMOC	$534.00
100 - 130 / 200 - 260 / 400 - 520	7"	21"	.10 %	SUPMOD	544.00
50 - 100 / 100 - 200 / 2 00 - 400	7"	21"	.25 %	SUPMOF	544.00

The above instruments in general limited to 3 scales due to the necessary scale space required for printing of scale numbering.

D.C. CURRENT INSTRUMENTS

Any current available from 200 microamperes and up. For special requirements, correspondence required.

SEN SITIV

Electrical MEASUREMENTS

VOLUME 27 NOVEMBER 1958 NUMBER 11

FEB - 4 1959 PM

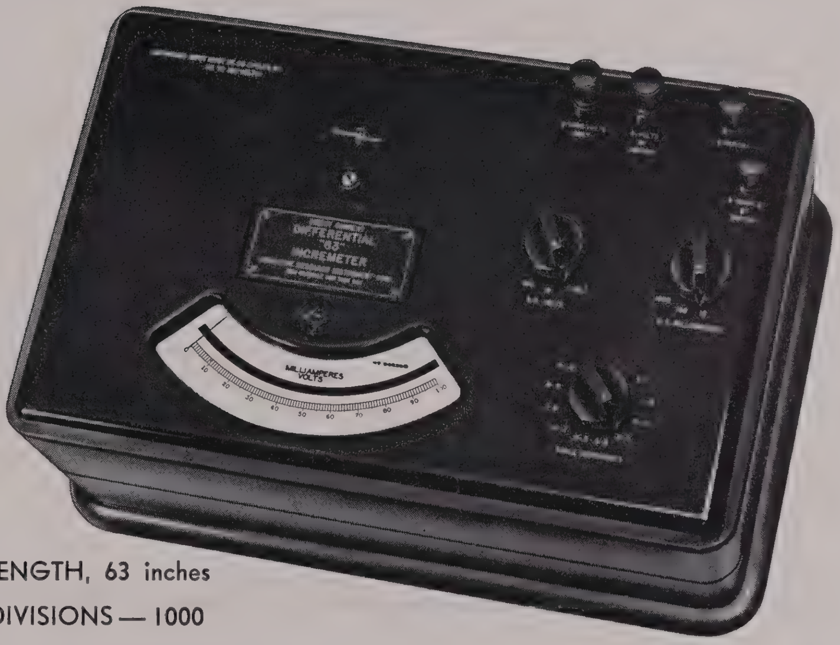
DIRECT CURRENT

DIFFERENTIAL "63" INCREMETER

MODEL INCRE

New!

PORTABLE
OR
PANEL MOUNTED



ACCURACY
.05 OF 1%

EFFECTIVE SCALE LENGTH, 63 inches
EFFECTIVE SCALE DIVISIONS — 1000

This new DIFFERENTIAL INCREMETER is a unique combination of the very old and the completely new in instrumentation. Differential instruments have been used for high accuracy comparisons for many years. Now, due to extensive development work at SENSITIVE RESEARCH we have combined differential instrument "High *COMPARATIVE* Accuracy" with a "HIGHLY Accurate" stable reference source and produced a 63 inch scale instrument with .05% accuracy. The DIFFERENTIAL INCREMETER has a 6.3 inch scale.

The addition of an expansion circuit allows this 6.3 inch scale to be effectively spread out to ten times its own length. This is accomplished by making it read in successive positions, zero to .1 full scale, .1 to .2 of full scale, .3 to .4 of full scale, etc. This enables an instrument "readability" never before attained in direct indicating instruments. It creates a 63 inch, ONE THOUSAND division scale, with an absolute accuracy of one-half division and stability and readability of a small fraction of this half division.

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

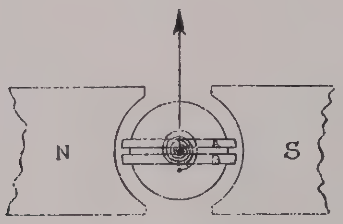
S
Symbol of Quality

DIFFERENTIAL "63" INCREMETER

ACCURACY .05 OF 1%

The torque producing mechanism of the well-known moving coil, permanent magnet type of instrument is an efficient device. The current through the moving coil which is sufficient to drive the pointer to full scale is relatively small in comparison to the maximum current carrying capacity of the wire used. Current of MANY TIMES the full scale current can be sent through the moving coil without causing overheating of the coil and consequent loss of accuracy. These higher currents must be applied slowly or the movement must be heavily damped to prevent mechanical damage as the pointer attempts to move to a position many times past full scale. This mechanical protection can be easily accomplished by means of eddy current damping.

The above "FACTS OF LIFE" for DC movements are exploited in the differential moving coil system shown in figure #1.



①

In this system there are two electrically independent coils wound on the same moving assembly. It is obvious that either of these coils can be used by itself to operate the pointer in a perfectly normal manner. When the two coils are supplied with current simultaneously and with the same polarity the torques produced by the respective currents will ADD and produce a deflection proportional to the SUM of the two currents. If, however, the two currents are supplied with OPPOSITE POLARITIES the net torque will be proportional to the DIFFERENCE of the two currents. When these two currents are equal to each other the net torque is ZERO regardless of their magnitude. Let us assume that we make a movement with a zero center pointer and with coils such that either one by itself will swing the pointer to full scale (left or right) for 50 milliamperes. If we further assume a 100 division scale marked 50 - 0 - 50, we have a complete and useful instrument. This movement can now be supplied with 49 milliamperes in one coil and 50 milliamperes in the other coil. The net torque of these two currents if they are of opposite polarity will be sufficient to cause a 1 division deflection in the direction of the larger current. If we know the 50 milliamperes to be accurate, we then know that the smaller current is 49 milliamperes (50 - 1). Our comparison sensitivity is 1 division. This is a 2% difference between the currents (1 div. in 50 equals 2%).

It is possible to take advantage of the inherent overload of the differential moving coil system as brought out in paragraph one. Instead of 49 and 50 milliamperes we can use currents of 499 and 500 milliamperes without in any way damaging the coils. A deflection will be obtained of one division, the same as before, because the difference is still 1 milliampere (500-499). However our comparison sensitivity is now 1 division in 500, or .2%, a gain in comparison sensitivity of 10 times, the exact factor by which we were able to run excess current through the movement. This basic increase in comparison sensitivity by making use of the overload characteristics of such moving coil systems has been recognized for many years. The only drawback to the realization of greater accuracy by use of differential instruments was in the obtaining of a satisfactory reference current to supply one of the two currents in order to change the HIGH COMPARATIVE accuracy into a HIGH ABSOLUTE ACCURACY. This ordinarily required a standard cell and galvanometer and constant rechecking and adjustment in order to maintain a satisfactory reference.

New "SENSITIVE RESEARCH" engineering advances in the design of miniature high stability power supplies have been used by us to produce a compact "BLACK BOX" reference source with very unusual characteristics. Using regulation—on regulation—on regulation techniques we have designed a compact supply capable of furnishing 1 milliampere D.C. reference currents from a 60 cycle line that are phenomenally stable. Within the limits of line voltage variations from 90 to 135 volts and ambient temperature variations of 10 to 40 degrees Centigrade, these supplies will furnish a reference 1 milliampere with a stability of appreciably better than .01% and with a design life expectancy in excess of 25,000 hours.

In figure #2 a typical differential movement is combined with our design stable reference source to provide an extremely high accuracy DC instrument with a wide range of measurement and several unique features. The basic differential movement in this case has a sensitivity of 0 to 100 microamperes in each section. If the instrument is used on the most sensitive current range (0 to 1 milliampere) and the switch on the reference half of the instrument is set at 0 - .1, there is no reference current supplied, and the instrument will deflect full scale for 100 microamperes (.1 of 1 milliampere). If the suppresion switch is now turned to the .1 - .2 position, a portion of the reference current is fed into the other half of the instrument moving coil system. Actually 100 microamperes is now flowing in the reference half and it would take 100 microamperes from the external source merely to bring the pointer to zero, therefore 200 microamperes will be required for full scale deflection. In other words the scale now reads not 0 to .1 milliamperes but .1 to .2 milliamperes. Similarly as we rotate the suppression switch we put greater currents through the reference half of the differential moving coil system and the scale reads progressively .2 to .3 ma., .3 to .4 ma., etc., up until with 900 microamperes flowing in the reference circuit, the scale reading is 0 to .1 milliampere. In effect we have "expanded" each tenth of the normal 0 to 1 milliampere scale of 6.3 inches into a full scale deflection of its own for a total effective scale length of 63 inches.

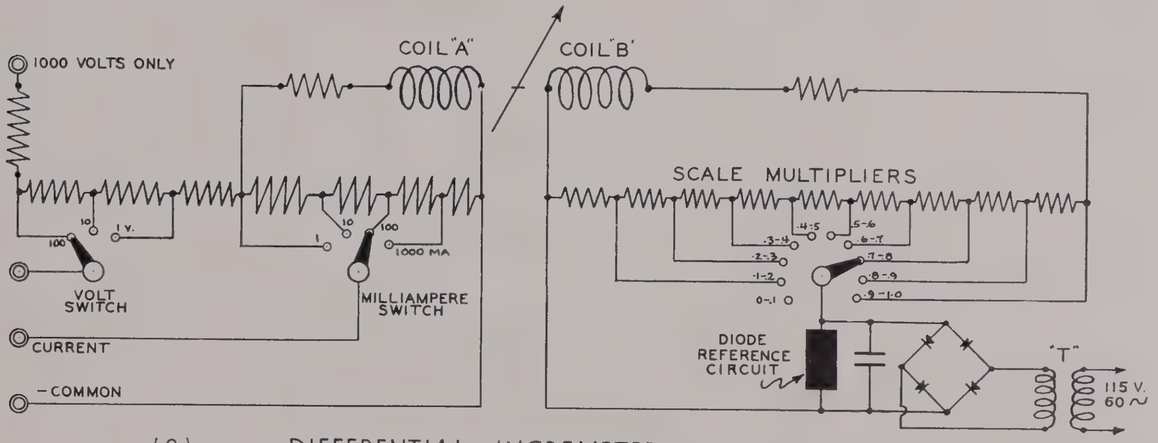
The accuracy of such a radically different type of instrument must be very carefully stated and understood for the completely satisfactory usage of this new instrument.

For any given range there are ten different sets of scale readings obtainable from 0 - .1 to .9 - 1.0 of the particular range involved. The accuracy is stated in terms of the FULL SCALE value of THE RANGE IN USE, regardless of what particular small section of that range the scale may be reading at the moment. This means that the 1 volt range which is spread over 63 inches of total scale length with 1000 scale divisions has an accuracy of .05% of full scale (.05% of 1 volt) which is ± .5 millivolt. This is true regardless of whether the scale is reading 0 - .1 volt, .2 - .3 volt or .9 - 1.0 volt at the moment. The accuracy is stated in terms of the full range in use without regard to the section which may be expanded at the time.

Accuracies are always stated in terms of Absolute values of current and/or voltage applied. In this particular type of instrument the resolution and repeatability of the readings are very markedly in excess of the absolute accuracy which can be guaranteed. Readings can easily be made to a resolution of .02% as this requires only the estimation of fifths of a division.

The repeatability of readings is even better than this, being in the order of .01%. These are phenomenal values of instrument readability and stability, never before achieved with direct reading instruments. These previously unheard of accuracies pose problems in the actual calibration of such instruments. For instance, in calibrating with the well known BROOKS POTENTIOMETER, (a widely used instrument in instrument standardizing laboratories) the pointer movement of the DIFFERENTIAL 63 INCREMETER is greater than the galvanometer pointer movement on the potentiometer. Many of the instrument's internal resistors must be adjusted using the instrument as its OWN INDICATOR because the instrument will show .01% variations quite readily which the usual bridges do not indicate. The very high readability of these instruments, (.1% is a full division) shows up power supply variations and similar slight variables that are ordinarily not noticed. In fact, until the user becomes familiar with this tremendous scale expansion it is very surprising to find that things are not quite as stable as believed.

We welcome suggestions from you — our customer friends — on possible applications of this new unusual measuring instrument development.



(2) DIFFERENTIAL INCREMETER CIRCUIT

ACCURACY .05 OF 1%

The accuracy is stated in terms of full scale of the range being used and is ± .05% of this value regardless of the scale expansion factor in use.

Over the total range spread of 0 - 1 MA. (0 - .1, .1 - .2 . . . . .9 - 1.0) the accuracy is ± .5 microampere The range spreads are as shown below:

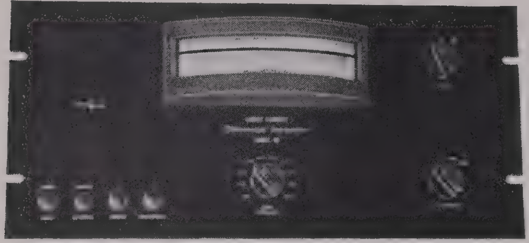
0 - 1 Ma. range spread is ± .5 Microampere	0 - 1 Volt range spread is ± .5 Millivolt
0 - 10 Ma. range spread is ± 5 Microamperes	0 - 10 Volt range spread is ± 5 Millivolts
0 - 100 Ma. range spread is ± 50 Microamperes	0 - 100 Volt range spread is ± 50 Millivolts
0 - 1000 Ma. range spread is ± .5 Milliampere	0 - 1000 Volt range spread is ± .5 Volt

The above accuracies apply for all positions of the range expansion switch. For example: 850 microamperes reads on the 1 ma. range with the expansion switch at .8 - .9 with an accuracy of ± .5 microampere.

Ranges	Code Word	Effective Scale Divisions	Price
1/10/100/1000 Volts (1000 ohms per volt) 1/10/100/1000 Milliamperes	SUPRES	1000	$860.00

(Total effective scale length, 63 inches)

Rack mounted "Incremeters" available — (see next page)



Size — 19″ x 8¾″
Depth behind panel — 5 inches
in Black Bakelite or Gray Finished Aluminum

PANEL MOUNTED D.C. DIFFERENTIAL "70" INCREMETER

Using our Edgewise reading panel instrument with its seven (7") inch scale length we have available an instrument with an effective 70" scale length.

All connections are available at binding posts on the front panel and on terminals in the rear for permanent wiring. The ranges are identical with that of the portable "63" Incremeter.

MODEL INCRE

ELECTRICALLY SUPPRESSED ZERO D. C. INSTRUMENTS

PORTABLE OR PANEL MOUNTED

PORTABLE CASE — 13¾″ x 7½″ x 8¼″

Using our new high stability power supply controlled by an almost unbelievably accurate diode reference circuit, we now have available a series of ELECTRICALLY SUPPRESSED ZERO instruments. Such instruments are markedly different and superior to any other suppressed zero, narrow range instruments.

The greater the electrical suppression, the greater the accuracy with this type of instrument, and suppressions of up to 90% are completely satisfactory and will allow accuracies of .05%.

The suppression current is obtained from the 115 volt 60 cycle line (available for 50 cycle on special order) and is regulated within .01% for line voltage variation between 90 and 130 volts and for a temperature range of 10 deg. C to 40 deg. C.

PANEL SIZE — See photo above

These instruments are extremely easy to use. Simply turn on power (115 volts, 60 cycles) and use. Power consumption from line is only 25 va.

This "NEW" SENSITIVE RESEARCH type of ELECTRICALLY SUPPRESSED ZERO instrument can be furnished in any range of current of 200 microamperes or more and any range of voltage of 200 millivolts or more and with any degree of expansion up to 90%. By 90% expansion is meant that for whatever the range of the instrument is only the portion from 90% to 100% appears on the scale and all values below 90% of full scale will be below the lowest scale marking, i.e.: off scale to the left in the usual instrument. Accuracies obtained will be as follows: 50% suppression gives .25% accuracy—80% suppression gives .1% accuracy and 90% suppression (the maximum allowable suppression) will give an accuracy of .05%. All accuracy values are given in terms of percentage of full scale.

POPULAR RANGES OF ELECTRICALLY SUPPRESSED ZERO DIRECT CURRENT VOLTMETERS

Ranges listed below are only samples of what can be furnished. The purchaser can select any range or ranges desired to fit the requirements of his application — as long as they are within the minimum specifications listed for the incremeter.

Full Scale Volts	Scale Length	Effective Scale Length	Accuracy % of Full Scale	Code Word	Price
6 - 7	7"	7"	.075%	SUPVOL	$464.00
6 - 8	7"	7"	.10 %	SUPVOM	464.00
12 - 14	7"	7"	.075%	SUPVOT	464.00
24 - 28	7"	7"	.075%	SUPVOK	464.00
110 - 120	7"	7"	.05 %	SUPVOY	464.00

Voltmeters available down to .2 volt full scale. Correspondence solicited.

MULTIRANGE D. C. VOLTMETERS

6 - 7 / 12 - 14 / 24 - 28	7"	21"	.075%	SUPMOB	$534.00
100 - 110 / 110 - 120 / 120 - 130	7"	21"	.05 %	SUPMOC	$534.00
100 - 130 / 200 - 260 / 400 - 520	7"	21"	.10 %	SUPMOD	544.00
50 - 100 / 100 - 200 / 2 00 - 400	7"	21"	.25 %	SUPMOF	544.00

The above instruments in general limited to 3 scales due to the necessary scale space required for printing of scale numbering.

D. C. CURRENT INSTRUMENTS

Any current available from 200 microamperes and up. For special requirements, correspondence required.

Electrical MEASUREMENTS

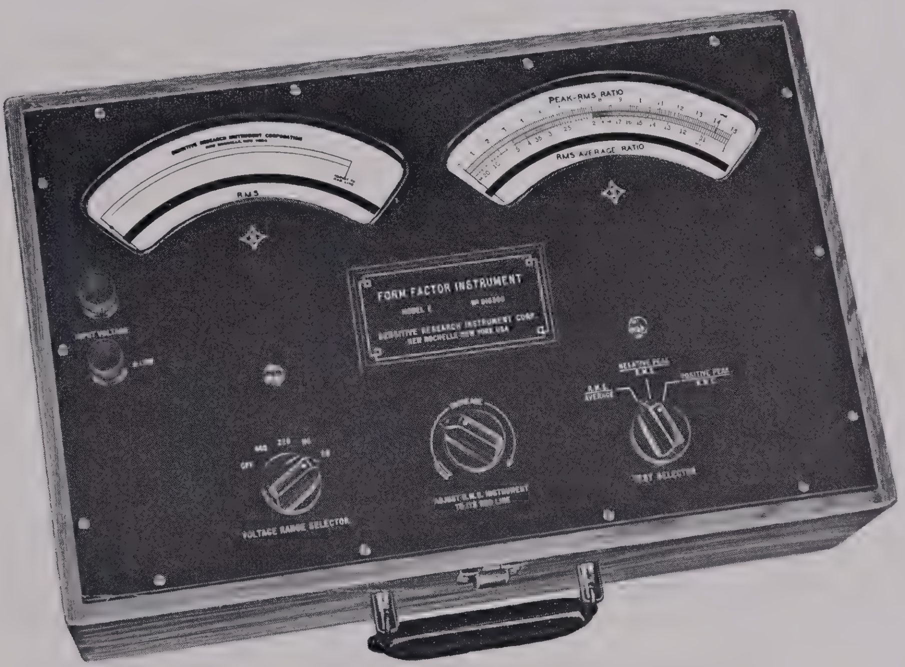
VOLUME 27 FEBRUARY, 1960 NUMBER 2

TWO NEW INSTRUMENTS
FORM FACTOR and POWER FACTOR

We are particularly pleased to describe herein these new instruments, which we believe, will be helpful in the type of electrical measurements required in industry today.

PORTABLE
FORM FACTOR
INSTRUMENT

MODEL **E**


PEAK-RMS RATIO
RMS AVERAGE RATIO
RMS
FORM FACTOR INSTRUMENT
SENSITIVE RESEARCH INSTRUMENT CORP.
NEW ROCHELLE NEW YORK USA
INPUT VOLTAGE
VOLTAGE RANGE SELECTOR
TEST SELECTOR

ACCURACY .2%

(See page 2)

FORM FACTOR INSTRUMENT

The SENSITIVE RESEARCH FORM FACTOR INSTRUMENT was designed to resolve the many discrepancies in electrical measurements which come up in day to day routine operations. Many types of instruments regularly used, give faulty indications when used on other than perfectly sinusoidal voltages or currents. Notably, the rectifier type voltage and current instruments which read usually 1.11 times the average value and most vacuum tube voltmeters, which read either the same 1.11 times average or .707 of peak, are bad offenders in this respect.

The usual assumption that the line voltage is sinusoidal is appreciably in error in many cases, particularly, when resonance type regulating transformers are in use. When small motor generators are used there is a tendency to flat top the generated wave. To further aggravate the situation, many devices, particularly those with ferro-magnetic cores, operate quite differently when a distorted wave is fed into them.

SENSITIVE RESEARCH
INSTRUMENT CORPORATION

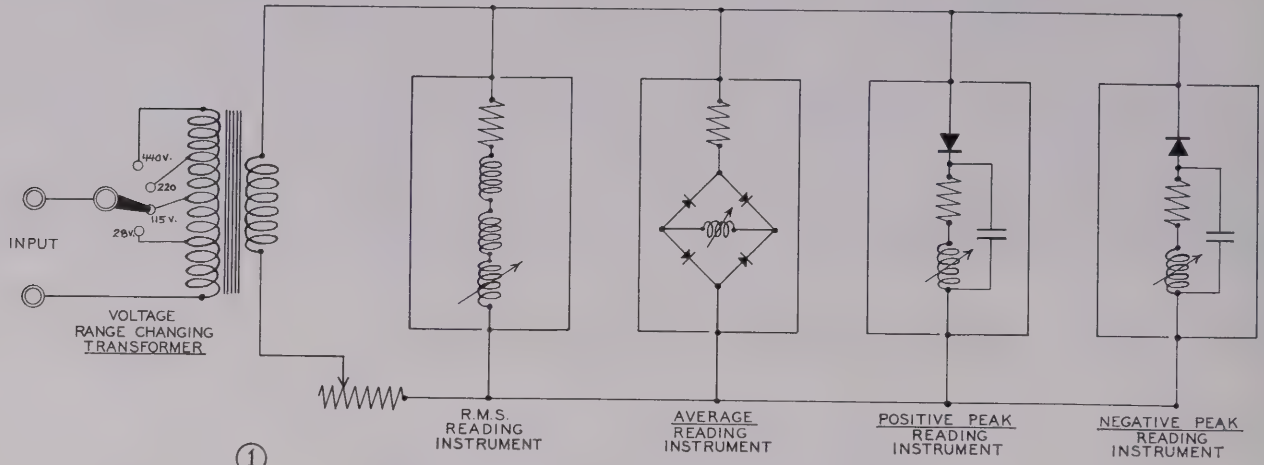
NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

Symbol of Quality

FORM FACTOR INSTRUMENTS

BASIC CIRCUITS OF THE FORM FACTOR INSTRUMENT


440V.
220
115 V.
28V
INPUT
VOLTAGE RANGE CHANGING TRANSFORMER
R.M.S. READING INSTRUMENT
AVERAGE READING INSTRUMENT
POSITIVE PEAK READING INSTRUMENT
NEGATIVE PEAK READING INSTRUMENT

①

BASIC CIRCUITS OF THE FORM FACTOR INSTRUMENT

All of these factors are fairly well understood but often tend to be neglected because of the difficulty in assigning NUMBERS to the errors involved. An oscilloscope examination will usually show up large significant distortions. A harmonic wave analyzer will, with sufficient time for operation establish the actual values of harmonic content. However, neither of these devices will establish the actual measurement error of instruments used on a distorted wave or derive a factor for the correction of such readings. This, the SENSITIVE RESEARCH FORM FACTOR INSTRUMENT does simply, rapidly, and accurately.

The basic circuits of the instruments are shown in Fig. 1. A high quality transformer is used in the input to allow operation at most of the common power voltages: 28, 115, 220 and 440 volts. The transformer is designed with a very low flux density and introduces negligible distortion for frequencies well beyond the rated 500 cycles. The transformer output is standardized in terms of its RMS value by means of a dynamometer instrument with extended frequency response. The series resistance covers approximately plus or minus 15% of the nominal input voltages for adjustment. By switching the appropriate circuits, AVERAGE VALUES, POSITIVE PEAKS or NEGATIVE PEAKS can be selected for display on the DC indicator of the FORM FACTOR INSTRUMENT. The scales of the DC indicator instead of being marked in terms of the actual voltages involved, are marked in terms of the ratios between RMS and the function designated. This is possible because we always standardize the RMS value to a single red line on the dynamometer scale.

The scales are marked in ratios of RMS/AVERAGE, POSITIVE PEAK/RMS, and NEGATIVE PEAK/RMS. If the line voltage in question is a PERFECT SINUSOID, the values read will be 1.11, 1.414 and 1.414 respectively and no correction factors need be applied to the readings of the instruments regardless of their type. If, however, the values are other than the 1.11 and 1.414 (values which are red lined on the scale), the reading corrections can easily be applied to instruments of known type to give accurate readings regardless of the distortion.

For AVERAGE indicating instruments the correction would be:

$$\frac{\text{RMS/Avg. ratio measured}}{1.11} \times \text{Reading of Average Reading Instrument.}$$

For PEAK reading instruments the correction would be:

$$\frac{\text{Peak/RMS ratio measured}}{1.414} \times \text{Reading of Peak Reading Instruments.}$$

The operation of the instrument is very simple. For 115 volt input a line cord with a three wire plug and an adaptor for two wire circuits is provided for connections. For voltages other than 115 volts, a pair of binding posts on the panel must be connected to the line. (These posts can also be used for 115 v. if more convenient.) The control marked "Adjust to Red Line" is turned until the instrument on the left side, the dynamometer, reads exactly on the red line. The right hand instrument will then give the exact ratio of RMS/AVERAGE or PEAK/RMS depending on the setting of the circuit switch. Separate scales are marked for RMS/AVERAGE and PEAK/RMS values, the appropriate scale must be read corresponding with the switch position in use.

THE FORM FACTOR INSTRUMENT is accurate from 25 to 500 cycles. The accuracy of ratio indication will be .2% or better, for ratios within 10% of the nominal 1.11 and 1.414 values. Accuracies of 1% will hold for ratios 1.1 or higher on PEAK/RMS ratio and ratios of 3.5 or lower on RMS/AVERAGE. Between 500 - 1000 cycles the above tolerances will be .3% and 2% respectively.

The SENSITIVE RESEARCH FORM FACTOR INSTRUMENT can be expected to clear up many unexplainable, or at least unproveable, instrumentation differences. It will prove to be a valuable tool for the engineer responsible for correlation of measurements between widely varying localities and between different operating groups. Further, in those cases where the waveform is non-sinusoidal, but is fixed in form, it will allow the use of any type instrumentation desired and immediately derive the correct constant for adjusting the error. This could only be done otherwise by a time consuming, difficult harmonic analysis and determination of the phase angle of each harmonic component and an elaborate mathematical synthesis of the wave components effective value.

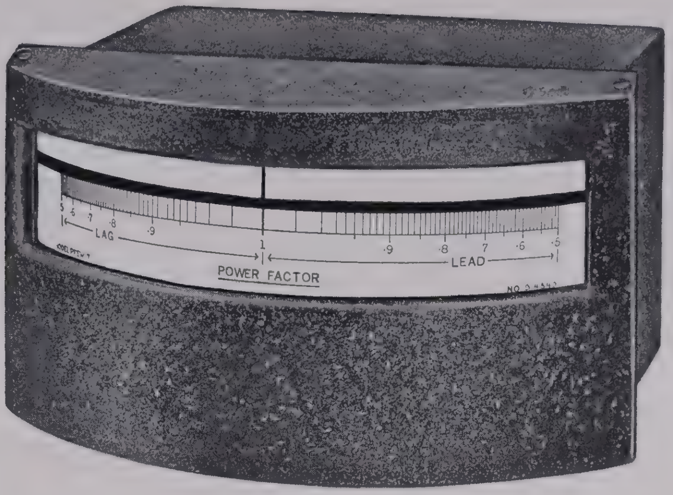
The standard instrument is furnished with ranges having maximum accuracies around the nominal 1.414 and 1.11 ratios of a sine wave. The actual scale ranges are 1.0 to 1.7 for ratios of peak to RMS and infinity to 1.0 for ratios of RMS to average. Special range instruments are available. Correspondence is solicited.

	Code		Price
Model E	EFFAP	Portable (hinged cover)	$ 870.00
Model E	EFFAP	Rack Mounting Panel	1025.00

ACCURACY

±.005

Power Factor

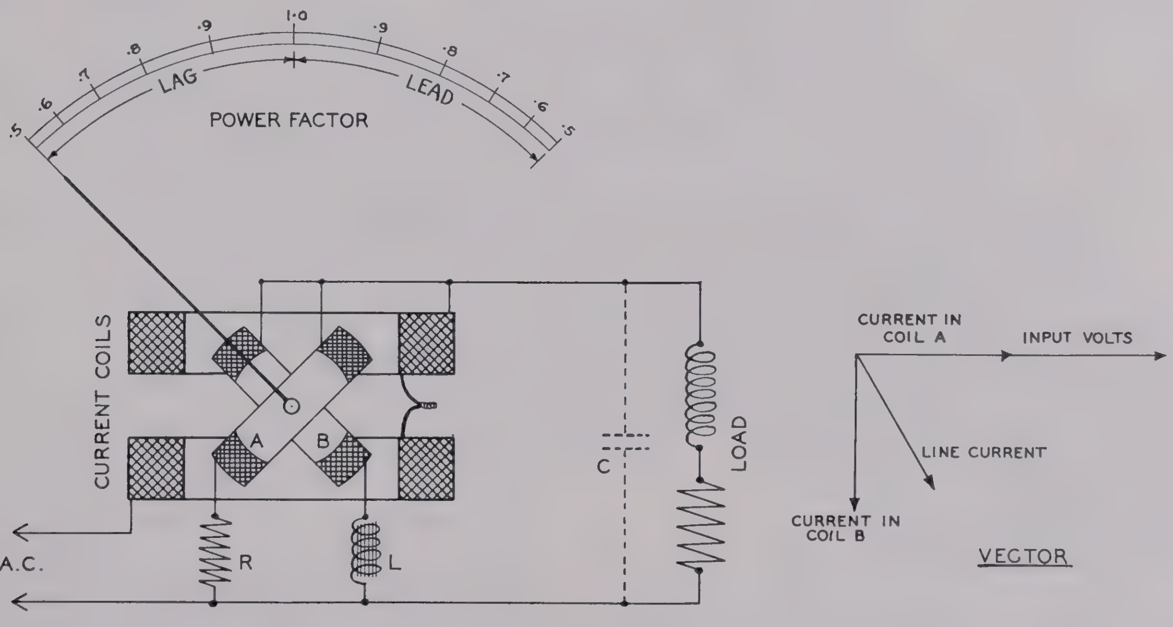


MODEL PFEW-7

Models PF (single phase) and PPF (polyphase) portable power factor instruments

Models PFEW-7 and PPFEW-7 are edgewise panel instruments with the same accuracy and performance characteristics as the portables (see illustration at left)

The SENSITIVE RESEARCH (Dynamometer Type) POWER FACTOR INSTRUMENT indicates the power factor of a circuit from 50% lag, through unity to 50% lead. Similar to a dynamometer wattmeter, the power factor instrument has a current and a potential circuit. The potential circuit consists of two parallel paths, one inductive and the other, non-inductive. The basic assembly is shown in Figure 2.



② BASIC POWER FACTOR INSTRUMENT

The current (field) coils are stationary and are connected in series or parallel depending upon the current range desired. The load current flows through the field coils and establishes a magnetic field. Rotating in that field is a moving coil system consisting of two coils A and B which are rigidly fixed at an angle of approximately 90° to each other. A pointer is attached to the coils to indicate the power factor on a calibrated instrument scale.

The currents in coils A and B are proportional to the load voltage and are led into the coils by fine ligaments which exert no appreciable torque. The resistance "R" has been added to coil A to make it a relatively non-inductive path. An inductor "L" is in series with coil B to create an inductive path. Thus, the current in coil B ALWAYS lags the current in coil A by 90°.

The pointer deflection depends upon the phase differences between the field current and the currents in the two branches of the potential circuits. The magnitude of the currents must only be large enough to overcome the very slight torque of the ligaments.

Since the impedance of the inductive path is dependent on frequency, the current in coil B will vary with frequency. For this reason, single phase power factor instruments are for use only at one frequency. Our single phase power factor instruments are made in two designs, for 60 cycle use and for 400 cycle circuits.

In Figure 2, an inductive load is shown connected to the power factor instruments. Therefore the pointer indicates a lagging power factor, and in the vector diagram, the line current is shown lagging the input voltage. The relationship between the vectors for currents in coils A and B always have the same relationship to the input voltage. Since coil A is resistive, its current vector is always in phase with the input voltage, while the current vector for the inductive path through coil B will always lag the input voltage vector by 90°.

Inductive loads are encountered in many applications. The lagging current taken by devices such as induction motors or transformers is objectionable and the practice of correcting the power factor by adding capacitance is commonly used in industry, as shown by "C" in Figure 2.

The use of the POWER FACTOR INSTRUMENT eliminates the need for calculating the necessary values of capacitance to correct a circuit, since it directly indicates the power factor condition. As load conditions change, the power factor instrument pointer would respond immediately, and the capacitance can be adjusted to the desired value.

A result of power factor correction is a reduced line current which in turn means reduced losses in the circuit and also results in better voltage regulation. In some cases a cost rate reduction for electrical service is obtained by adjusting the power factor toward unity.

For balanced 3 phase loads a POLYPHASE POWER FACTOR instrument is also available. There is a slight difference in construction. No inductive path is necessary because the instrument obtains the required phase difference in the potential circuit from the 120° phase angle in a three phase system. Both potential circuits in this case are made resistive.

These power factor instruments are furnished in standard ranges of voltages and currents. Voltage ranges are 115 volts and 230 volts. Current ranges are either 2.5/5 amperes or 5/10 amperes. For single phase operation, instruments can be furnished either with 2 voltage ranges at a single frequency, or with one voltage range for use at two frequencies. The available ranges are 115 and 230 volts, and 60 and 400 cycles. Polyphase instruments for use on balanced loads are available for single voltages or for both 115 and 230 volts. All standard polyphase instruments operate from 50 to 500 cycles satisfactorily. All voltage circuits can vary +10% and —30% without affecting accuracy of indications.

All standard instruments cover power factor ranges of .5 lag through 1.0 to .5 lead and have an accuracy of ±.005 power factor.

Instruments can be furnished in portable formica cases or in our panel mounted EW-5 (5" scale) or EW-7 (7" scale) black aluminum cases.

Range .5 - 1 - .5 Power Factor

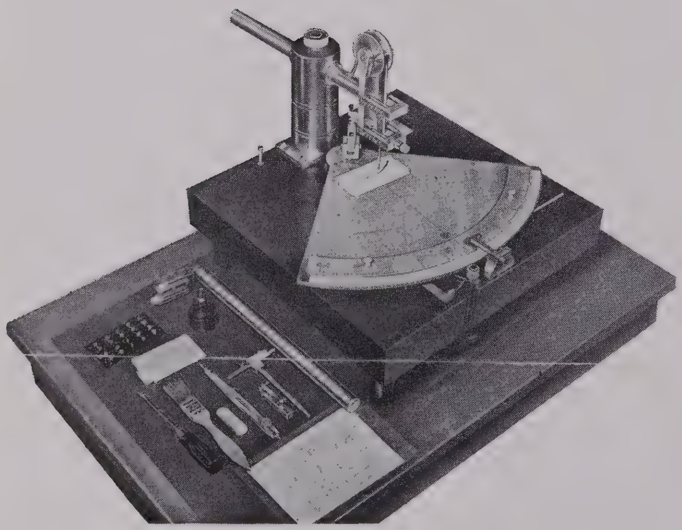
Model PF (Single phase — Specify either double frequency single voltage or single frequency double voltage. Give current and voltage ranges.) Code PFISP Price $575.00

Model PPF (Polyphase — Specify whether for 3 or 4 wire circuits, 2 or 3 phase. Give voltage ranges, current ranges and frequency span.) Code PFIPP Price $550.00

Above instruments, mounted in type EW-7 edgewise panel case (Models PFEW-7 and PPFEW-7) add $30.00 to portable prices.

SCALE DRAWING MACHINE

MODEL **SCAMA**



The SENSITIVE RESEARCH scale-drawing machine is a hand operated device that will allow the redrawing of any electrical indicating instrument's scale whose angular deflection is no greater than *110 degrees. The machine is designed so that instruments which are individually calibrated can have their scales redrawn to primary standard accuracy. It is essential equipment for all government, military, and industrial repair depots whose primary function is the maintenance and servicing of electrical and electronic equipment.

This Scale Drawing Machine is a duplicate of those we have used in our laboratory since 1927 and it is capable of drawing precision scales to all the accuracy that the resolution of an instrument will permit.

With the purchase of this machine, we offer without charge, a forty (40) hour course of instruction. This course, given at the Sensitive Research laboratories only, covers the use, care and maintenance of the Scale Drawing Machine.

The use of this machine will help reduce the "down time" of an instrument being repaired, and also eliminate the sometimes tedious efforts to match an existing instrument scale. The drawing of a new scale in a very short time will definitely reduce repair time costs. Shipping charges are eliminated in that the instrument does not have to go back and forth to its manufacturer for the drawing of a new scale to the instrument's original accuracy.

UNIVERSAL FLAT SCALE DRAWING MACHINE
Model SCAMA Price $3800.00
*Attachment for drawing 270° scales Price $394.00

For the past 32 years we have published this company bulletin "ELECTRICAL MEASUREMENTS." In it we describe new and unusual instruments and measurement techniques. It is mailed without cost to interested persons. If you wish to receive this publication, please advise us.

Electrical
MEASUREMENTS

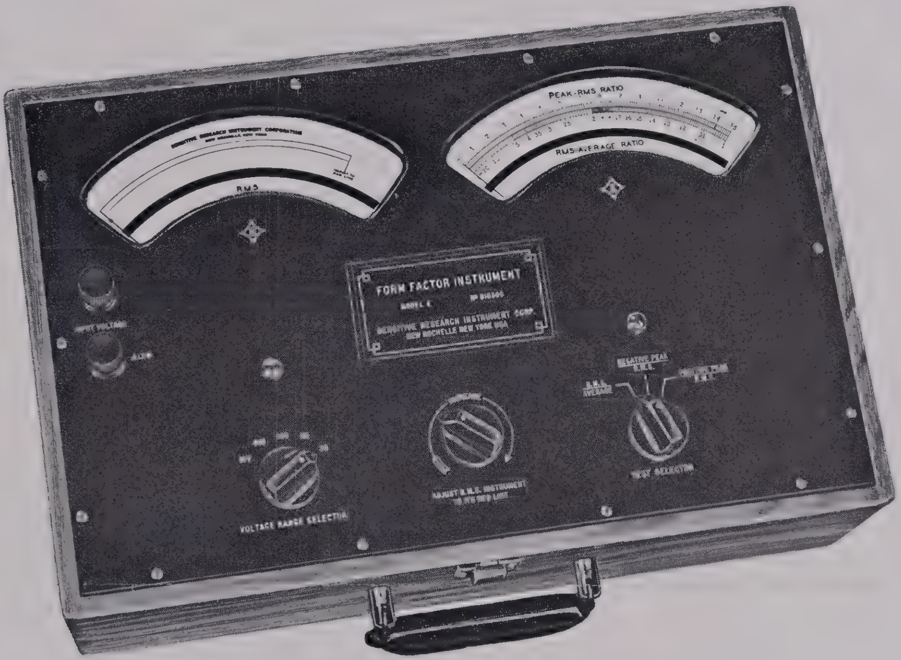
VOLUME 27 FEBRUARY, 1960 NUMBER 2

TWO NEW INSTRUMENTS
FORM FACTOR and POWER FACTOR

We are particularly pleased to describe herein these new instruments, which we believe, will be helpful in the type of electrical measurements required in industry today.

PORTABLE
FORM FACTOR
INSTRUMENT

MODEL **E**


PEAK-RMS RATIO
RMS-AVERAGE RATIO
RMS
FORM FACTOR INSTRUMENT
MODEL E
SENSITIVE RESEARCH INSTRUMENT CORP.
NEW ROCHELLE NEW YORK USA
NEGATIVE PEAK R.M.S.
R.M.S. AVERAGE
VOLTAGE RANGE SELECTOR
ADJUST R.M.S. INSTRUMENT TO RED LINE
TEST SELECTOR

ACCURACY .2%

(See page 2)

FORM FACTOR INSTRUMENT

The SENSITIVE RESEARCH FORM FACTOR INSTRUMENT was designed to resolve the many discrepancies in electrical measurements which come up in day to day routine operations. Many types of instruments regularly used, give faulty indications when used on other than perfectly sinusoidal voltages or currents. Notably, the rectifier type voltage and current instruments which read usually 1.11 times the average value and most vacuum tube voltmeters, which read either the same 1.11 times average or .707 of peak, are bad offenders in this respect.

The usual assumption that the line voltage is sinusoidal is appreciably in error in many cases, particularly, when resonance type regulating transformers are in use. When small motor generators are used there is a tendency to flat top the generated wave. To further aggravate the situation, many devices, particularly those with ferro-magnetic cores, operate quite differently when a distorted wave is fed into them.

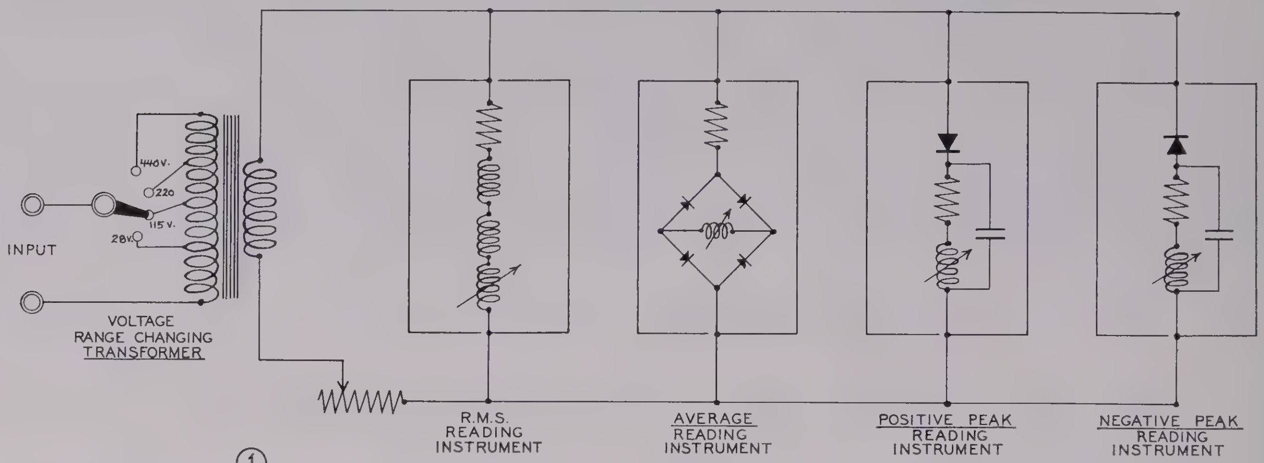
SENSITIVE RESEARCH
INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

Symbol of Quality

BASIC CIRCUITS OF THE FORM FACTOR INSTRUMENT


440V.
220
115 V.
28V.
INPUT
VOLTAGE RANGE CHANGING TRANSFORMER
R.M.S. READING INSTRUMENT
AVERAGE READING INSTRUMENT
POSITIVE PEAK READING INSTRUMENT
NEGATIVE PEAK READING INSTRUMENT

①

BASIC CIRCUITS OF THE FORM FACTOR INSTRUMENT

All of these factors are fairly well understood but often tend to be neglected because of the difficulty in assigning NUMBERS to the errors involved. An oscilloscope examination will usually show up large significant distortions. A harmonic wave analyzer will, with sufficient time for operation establish the actual values of harmonic content. However, neither of these devices will establish the actual measurement error of instruments used on a distorted wave or derive a factor for the correction of such readings. This, the SENSITIVE RESEARCH FORM FACTOR INSTRUMENT does simply, rapidly, and accurately.

The basic circuits of the instruments are shown in Fig. 1. A high quality transformer is used in the input to allow operation at most of the common power voltages: 28, 115, 220 and 440 volts. The transformer is designed with a very low flux density and introduces negligible distortion for frequencies well beyond the rated 500 cycles. The transformer output is standardized in terms of its RMS value by means of a dynamometer instrument with extended frequency response. The series resistance covers approximately plus or minus 15% of the nominal input voltages for adjustment. By switching the appropriate circuits, AVERAGE VALUES, POSITIVE PEAKS or NEGATIVE PEAKS can be selected for display on the DC indicator of the FORM FACTOR INSTRUMENT. The scales of the DC indicator instead of being marked in terms of the actual voltages involved, are marked in terms of the ratios between RMS and the function designated. This is possible because we always standardize the RMS value to a single red line on the dynamometer scale.

The scales are marked in ratios of RMS/AVERAGE, POSITIVE PEAK/RMS, and NEGATIVE PEAK/RMS. If the line voltage in question is a PERFECT SINUSOID, the values read will be 1.11, 1.414 and 1.414 respectively and no correction factors need be applied to the readings of the instruments regardless of their type. If, however, the values are other than the 1.11 and 1.414 (values which are red lined on the scale), the reading corrections can easily be applied to instruments of known type to give accurate readings regardless of the distortion.

For AVERAGE indicating instruments the correction would be:

$$\frac{\text{RMS/Avg. ratio measured}}{1.11} \times \text{Reading of Average Reading Instrument.}$$

For PEAK reading instruments the correction would be:

$$\frac{\text{Peak/RMS ratio measured}}{1.414} \times \text{Reading of Peak Reading Instruments.}$$

The operation of the instrument is very simple. For 115 volt input a line cord with a three wire plug and an adaptor for two wire circuits is provided for connections. For voltages other than 115 volts, a pair of binding posts on the panel must be connected to the line. (These posts can also be used for 115 v. if more convenient.) The control marked "Adjust to Red Line" is turned until the instrument on the left side, the dynamometer, reads exactly on the red line. The right hand instrument will then give the exact ratio of RMS/AVERAGE or PEAK/RMS depending on the setting of the circuit switch. Separate scales are marked for RMS/AVERAGE and PEAK/RMS values, the appropriate scale must be read corresponding with the switch position in use.

THE FORM FACTOR INSTRUMENT is accurate from 25 to 500 cycles. The accuracy of ratio indication will be .2% or better, for ratios within 10% of the nominal 1.11 and 1.414 values. Accuracies of 1% will hold for ratios 1.1 or higher on PEAK/RMS ratio and ratios of 3.5 or lower on RMS/AVERAGE. Between 500 - 1000 cycles the above tolerances will be .3% and 2% respectively.

The SENSITIVE RESEARCH FORM FACTOR INSTRUMENT can be expected to clear up many unexplainable, or at least unproveable, instrumentation differences. It will prove to be a valuable tool for the engineer responsible for correlation of measurements between widely varying localities and between different operating groups. Further, in those cases where the waveform is non-sinusoidal, but is fixed in form, it will allow the use of any type instrumentation desired and immediately derive the correct constant for adjusting the error. This could only be done otherwise by a time consuming, difficult harmonic analysis and determination of the phase angle of each harmonic component and an elaborate mathematical synthesis of the wave components effective value.

The standard instrument is furnished with ranges having maximum accuracies around the nominal 1.414 and 1.11 ratios of a sine wave. The actual scale ranges are 1.0 to 1.7 for ratios of peak to RMS and infinity to 1.0 for ratios of RMS to average. Special range instruments are available. Correspondence is solicited.

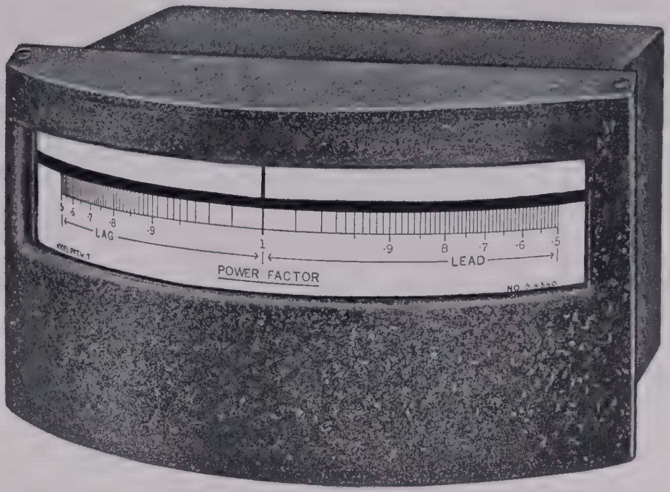
	Code		Price
Model E	EFFAP	Portable (hinged cover)	$ 870.00
Model E	EFFAP	Rack Mounting Panel	1025.00

POWER FACTOR INSTRUMENTS

ACCURACY

±.005

Power Factor



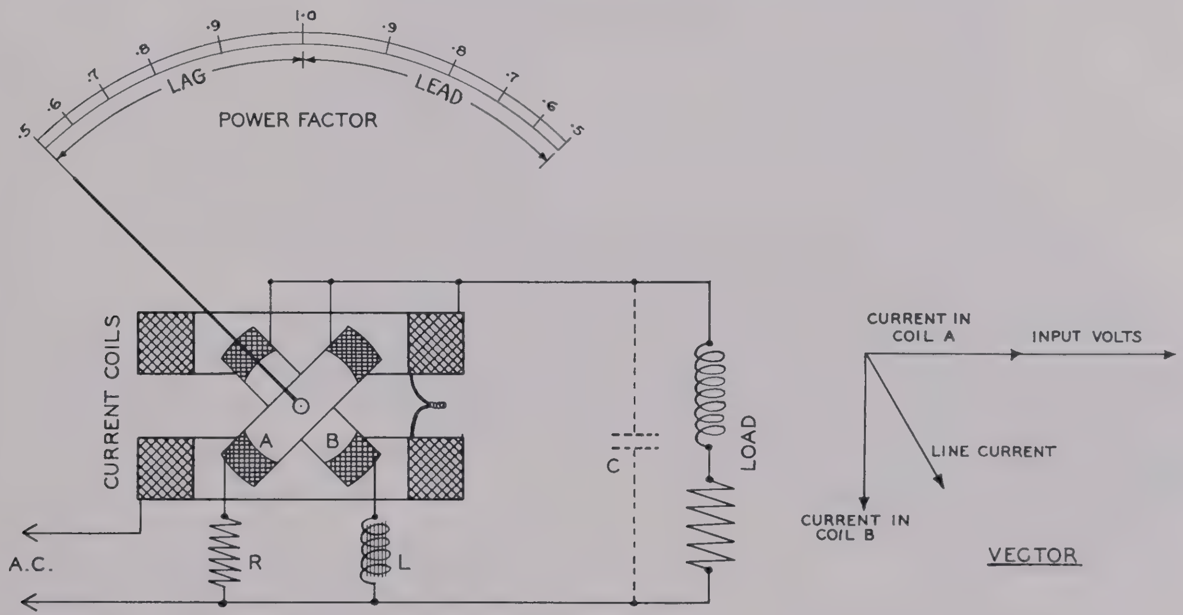
MODEL PFEW-7

Models PF (single phase) and PPF (polyphase) portable power factor instruments

Models PFEW-7 and PPFEW-7 are edgewise panel instruments with the same accuracy and performance characteristics as the portables (see illustration at left)

The SENSITIVE RESEARCH (Dynamometer Type) POWER FACTOR INSTRUMENT indicates the power factor of a circuit from 50% lag, through unity to 50% lead. Similar to a dynamometer wattmeter, the power factor instrument has a current and a potential circuit. The potential circuit consists of two parallel paths, one inductive and the other, non-inductive. The basic assembly is shown in Figure 2.

The current (field) coils are stationary and are connected in series or parallel depending upon the current range desired. The load current flows through the field coils and establishes a magnetic field. Rotating in that field is a moving coil system consisting of two coils A and B which are rigidly fixed at an angle of approximately 90° to each other. A pointer is attached to the coils to indicate the power factor on a calibrated instrument scale.



② BASIC POWER FACTOR INSTRUMENT

The currents in coils A and B are proportional to the load voltage and are led into the coils by fine ligaments which exert no appreciable torque. The resistance "R" has been added to coil A to make it a relatively non-inductive path. An inductor "L" is in series with coil B to create an inductive path. Thus, the current in coil B ALWAYS lags the current in coil A by 90°.

The pointer deflection depends upon the phase differences between the field current and the currents in the two branches of the potential circuits. The magnitude of the currents must only be large enough to overcome the very slight torque of the ligaments.

Since the impedance of the inductive path is dependent on frequency, the current in coil B will vary with frequency. For this reason, single phase power factor instruments are for use only at one frequency. Our single phase power factor instruments are made in two designs, for 60 cycle use and for 400 cycle circuits.

In Figure 2, an inductive load is shown connected to the power factor instruments. Therefore the pointer indicates a lagging power factor, and in the vector diagram, the line current is shown lagging the input voltage. The relationship between the vectors for currents in coils A and B always have the same relationship to the input voltage. Since coil A is resistive, its current vector is always in phase with the input voltage, while the current vector for the inductive path through coil B will always lag the input voltage vector by 90°.

Inductive loads are encountered in many applications. The lagging current taken by devices such as induction motors or transformers is objectionable and the practice of correcting the power factor by adding capacitance is commonly used in industry, as shown by "C" in Figure 2.

The use of the POWER FACTOR INSTRUMENT eliminates the need for calculating the necessary values of capacitance to correct a circuit, since it directly indicates the power factor condition. As load conditions change, the power factor instrument pointer would respond immediately, and the capacitance can be adjusted to the desired value.

A result of power factor correction is a reduced line current which in turn means reduced losses in the circuit and also results in better voltage regulation. In some cases a cost rate reduction for electrical service is obtained by adjusting the power factor toward unity.

For balanced 3 phase loads a POLYPHASE POWER FACTOR instrument is also available. There is a slight difference in construction. No inductive path is necessary because the instrument obtains the required phase difference in the potential circuit from the 120° phase angle in a three phase system. Both potential circuits in this case are made resistive.

These power factor instruments are furnished in standard ranges of voltages and currents. Voltage ranges are 115 volts and 230 volts. Current ranges are either 2.5/5 amperes or 5/10 amperes. For single phase operation, instruments can be furnished either with 2 voltage ranges at a single frequency, or with one voltage range for use at two frequencies. The available ranges are 115 and 230 volts, and 60 and 400 cycles. Polyphase instruments for use on balanced loads are available for single voltages or for both 115 and 230 volts. All standard polyphase instruments operate from 50 to 500 cycles satisfactorily. All voltage circuits can vary +10% and —30% without affecting accuracy of indications.

All standard instruments cover power factor ranges of .5 lag through 1.0 to .5 lead and have an accuracy of ±.005 power factor.

Instruments can be furnished in portable formica cases or in our panel mounted EW-5 (5" scale) or EW-7 (7" scale) black aluminum cases.

Range .5 - 1 - .5 Power Factor

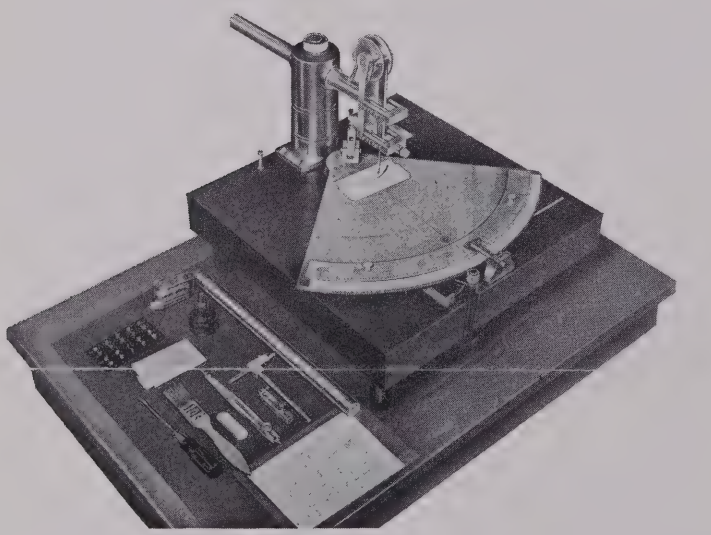
Model PF (Single phase — Specify either double frequency single voltage or single frequency double voltage. Give current and voltage ranges.) Code PFISP Price $575.00

Model PPF (Polyphase — Specify whether for 3 or 4 wire circuits, 2 or 3 phase. Give voltage ranges, current ranges and frequency span.) Code PFIPP Price $550.00

Above instruments, mounted in type EW-7 edgewise panel case (Models PFEW-7 and PPFEW-7) add $30.00 to portable prices.

SCALE DRAWING MACHINE

MODEL **SCAMA**



The SENSITIVE RESEARCH scale-drawing machine is a hand operated device that will allow the redrawing of any electrical indicating instrument's scale whose angular deflection is no greater than *110 degrees. The machine is designed so that instruments which are individually calibrated can have their scales redrawn to primary standard accuracy. It is essential equipment for all government, military, and industrial repair depots whose primary function is the maintenance and servicing of electrical and electronic equipment.

This Scale Drawing Machine is a duplicate of those we have used in our laboratory since 1927 and it is capable of drawing precision scales to all the accuracy that the resolution of an instrument will permit.

With the purchase of this machine, we offer without charge, a forty (40) hour course of instruction. This course, given at the Sensitive Research laboratories only, covers the use, care and maintenance of the Scale Drawing Machine.

The use of this machine will help reduce the "down time" of an instrument being repaired, and also eliminate the sometimes tedious efforts to match an existing instrument scale. The drawing of a new scale in a very short time will definitely reduce repair time costs. Shipping charges are eliminated in that the instrument does not have to go back and forth to its manufacturer for the drawing of a new scale to the instrument's original accuracy.

UNIVERSAL FLAT SCALE DRAWING MACHINE
Model SCAMA Price $3800.00
*Attachment for drawing 270° scales Price $394.00

For the past 32 years we have published this company bulletin "ELECTRICAL MEASUREMENTS." In it we describe new and unusual instruments and measurement techniques. It is mailed without cost to interested persons. If you wish to receive this publication, please advise us.

Electrical MEASUREMENTS

VOLUME 27 FEBRUARY 1959 NUMBER 1

50-800 CYCLE
VOLT-AMPERE-WATTMETER

INSTRUMENT
TRANSFORMER COUPLED
DYNAMOMETER
MOVEMENT

FORMICA CASE
AVAILABLE

ACCURACY
.5 of 1% for Volts and Amperes
.75 of 1% for Watts

In the average laboratory, power line measurements of VOLTAGE, CURRENT AND POWER are probably the most frequently made measurements. For such measurements there is not a better single instrument than the Sensitive Research, Model VAW, volt-amp-wattmeter. With this single instrument, one can make HIGH ACCURACY power frequency measurements over a very wide range. If yours is the laboratory that does no military or aircraft work, then the code VOLTAWATT, with 50 - 125 cycle response, will be ample for your operation. If you also cover the extensive 400 cycle useage required in military and aviation work, the code VOLTOWATT, with its 50 - 800 cycle response, is the instrument for your work.

Either of these instruments can be inserted in the line and used for making ACCURATE measurements of input voltages, currents or watts. Any readings taken will be direct tare-free readings and the instrument can be switched from one electrical quantity to another without, in any way, changing the series impedance or the shunt load.

SENSITIVE RESEARCH
INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

S

Symbol of Quality

It is a VOLTMETER, an AMMETER and a WATTMETER

From *50 to 800 Cycles

AS A VOLTMETER

Set the selector switch on VOLTS and connect to the COMMON and VOLTS terminals to obtain a dynamometer voltmeter. The sensitivity is 100 ohms per volt (10 milliamperes) and full accuracy on all ranges for the rated frequencies. In addition, the instrument can measure DIRECT CURRENT volts. On the 25 volt and 50 volt ranges, the accuracy is 1%.

AS AN AMMETER

Set the selector switch on AMPERES and connect to the COMMON and the AMPERES post to obtain a dynamometer ammeter. This will give full accuracy on all ranges to the rated frequency. The AMMETER cannot be used on DC as the ranges are obtained by means of a current transformer.

AS A VOLT-AMP-WATTMETER

Connect line to INPUT terminals and the load to LOAD terminals and the instrument is a VOLT-AMP-WATTMETER. Set range switches for proper values of volts and amperes. By rotation of the selector switch, Volts, Amperes or Watts can be read with true net values. DC watts cannot be measured, but full accuracy is obtained at the frequencies specified below for the code VOLTOWATT (50 - 800 cycles) and for full rated frequency (50 - 125 cycles) for code VOLTAWATT.

FOR POWER FACTOR

The VAW will give an excellent measurement of power factor by merely taking readings of volts, amperes and watts separately, then:

$$\text{Power factor} = \frac{\text{Watt reading}}{\text{VA reading}}$$

Our VOLT-AMP-WATTMETER has an accuracy of .75 of 1% on WATTS; on VOLTS and AMPERES, .5 of 1%. Its scale length of 5.2 inches is very easily read. It is supplied in an American Walnut or Formica case with chrome plated fittings; dimensons 13¾" x 7½" x 6½". This is a beautiful appearing instrument with a black moulded bakelite panel.

The utility and general economy of the Volt-Amp-Wattmeter makes it a MUST in any progressive laboratory. SENSITIVE RESEARCH instruments are unconditionally guaranteed as to workmanship and materials for a period of one year. We guarantee our instruments to maintain their described accuracies, provided they are NOT ABUSED and that the instrument seal is not broken.

STANDARD
VOLT-AMP-WATTMETER

Frequency from *50 to 125 cycles

VOLTS	Lowest Reading
25	5 volts
50	10 volts
100	20 volts
200	40 volts
500	100 volts

(Resistance 100 ohms per volt)

Code VOLTAWATT Price $405.00

With Formica Case supplied — add $15.00

AMPERES	Lowest Reading
.010	2 Milliamperes
.5	100 Milliamperes
1.0	200 Milliamperes
5.0	1 Ampere
10.0	2 Amperes

5 Ranges of VOLTS
5 Ranges of CURRENT
12 Ranges of WATTS

WATTS	Lowest Reading
12.5	.125 watt
25.0	.25 watt
50.0	.5 watt
100.0	1.0 watt
125.0	1.25 watts
200.0	2.0 watts
250.0	2.5 watts
500.0	5.0 watts
1000.0	10.0 watts
2000.0	20.0 watts
2500.0	25.0 watts
5000.0	50.0 watts

**The instrument can be used down to Power Factors of 50% at 25 - 125 cycles at full accuracy, at 400 cycles 50% P.F. accuracy is 1½%, at 800 cycles, 50% P.F. accuracy is 3%, for 100% P.F., full accuracy to 800 cycles.*

SPECIAL
VOLT-AMP-WATTMETER

When this VOLT-AMP-WATTMETER is supplied for use from 50 to 800 cycles, the following ranges only are supplied:

Frequency from *50 to 800 cycles

VOLTS	Lowest Reading
100	20 volts
200	40 volts
500	100 volts

Code VOLTOWATT Price $430.00

With Formica Case supplied — add $15.00

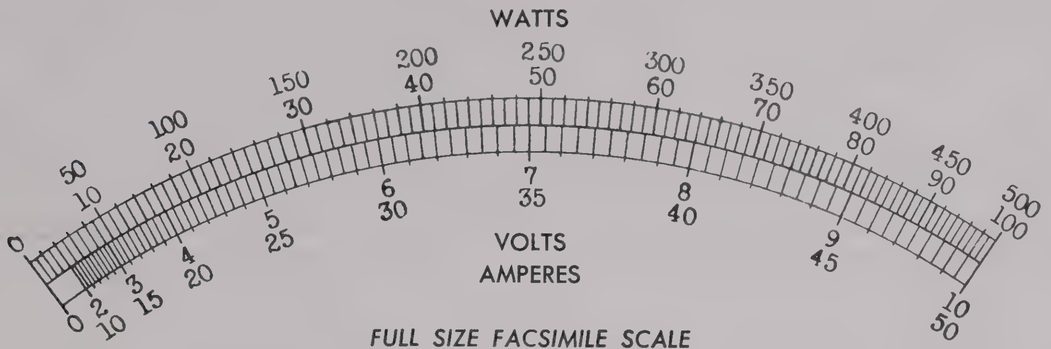
AMPERES	Lowest Reading
.010	2 Milliamperes
.5	100 Milliamperes
1.0	200 Milliamperes
5.0	1 Ampere
10.0	2 Amperes

3 Ranges of VOLTS
5 Ranges of CURRENT
9 Ranges of WATTS

WATTS	Lowest Reading
50	.5 watt
100	1.0 watt
200	2.0 watts
250	2.5 watts
500	5.0 watts
1000	10.0 watts
2000	20.0 watts
2500	25.0 watts
5000	50.0 watts

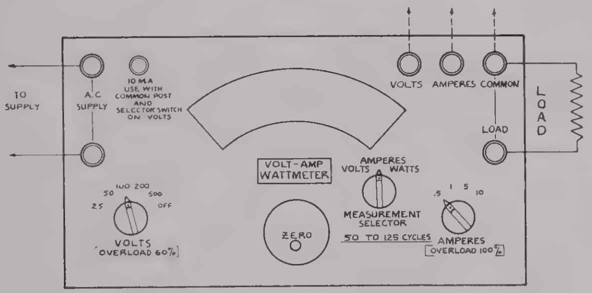
SOMETHING NEW HAS BEEN ADDED!

The VAW instrument is so very versatile that additions seem rather hard to come by. However, the new VAW does have an addition to its family of possible uses. The basic movement of all of the VAWs is a ten milliampere instrument and we have added a separate binding post to make this basic sensitivity available externally. A small red binding post is mounted on the panel and by using this post and the COMMON post with the switch on the VOLTS position the basic 10 milliampere sensitivity of the instrument is available for use with external multipliers or for high sensitivity current measurements. The post is separate and distinct from other posts to prevent any inadvertent use of this high sensitivity tap for other purposes.


WATTS
0
50
100
150
200
250
300
350
400
450
500
10
20
30
40
50
60
70
80
90
100
0
2
3
4
5
6
7
8
9
10
10
15
20
25
30
35
40
45
50
VOLTS
AMPERES

FULL SIZE FACSIMILE SCALE

These instruments accomplish all of the measurements without changing the connections. All necessary switching is internally controlled by positive detent selector switches. It is extremely simple to make external connections to measure the VOLTS applied to the load, the load AMPERES and the WATTS. (See Figure 2.)

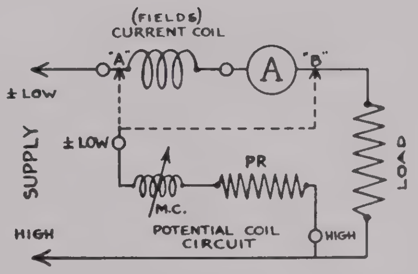

TO SUPPLY
A.C SUPPLY
10 M.A USE WITH COMMON POST AND SELECTOR SWITCH ON VOLTS
VOLTS
AMPERES
COMMON
LOAD
LOAD
VOLT-AMP WATTMETER
AMPERES
VOLTS
WATTS
MEASUREMENT SELECTOR
50 TO 125 CYCLES
100 200
50
500
25
OFF
VOLTS
OVERLOAD 60%
ZERO
.5
1
5
10
AMPERES
OVERLOAD 100%

Connections for use as a separate ammeter or voltmeter

The indicating instrument is an accurate, rugged magnetically shielded dynamometer. The transformer is shielded and is designed for 50 - 800 cycle use.

This new VOLT-AMP-WATTMETER is completely compensated and NO calculations are necessary by the user. Compensation is accomplished by a special winding "A" on the internal current transformer which opposes the normal LOAD CURRENT flux by the current flowing in the potential circuit. This reduces the wattmeter reading by the amount of power lost in the potential circuit and therefore the VOLT-AMP-WATTMETER indicates true load WATTS.

All non-compensated wattmeters read high by the power consumed in the usual wattmeter potential circuit or the power lost in the current circuit, depending upon the connections used. See figure 1.


(FIELDS)
CURRENT COIL
"A"
A
"B"
± LOW
SUPPLY
± LOW
PR
M.C.
LOAD
HIGH
POTENTIAL COIL CIRCUIT
HIGH

FUNDAMENTAL CIRCUIT

Figure 1

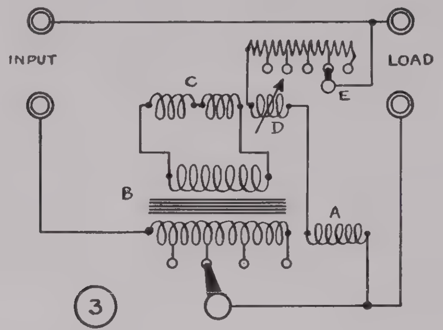
Wattmeters are usually connected to the supply line and to the load, as shown in figure 1. The end of the potential coil can be joined to either "A" or "B." REGARDLESS of which connection is chosen, the wattmeter will read HIGH by the power consumed in either the potential coil circuit or by the power consumed in the current coil and ammeter—depending on whether the "A" or "B" connection is used. The wattmeter will NEVER read high by the power consumed in BOTH circuit elements.

If connected to "A," the wattmeter reads load power plus I^2R *loss in current coils and ammeter. If connected to "B," the wattmeter reads load power plus* $\frac{E^2}{R}$ *loss in potential coil circuit.*

In the usual non-compensated wattmeter it is therefore necessary to calculate the losses in watts and subtract this value from the reading, for accurate results.

In this VOLT-AMP-WATTMETER we use the "B" connection and internally compensate for the potential circuit losses.

The internal circuits used for completely "tare free" readings of all parameters are shown in Fig. 3, 4 and 5. When the load circuit is fed through the instrument with the selector switch on "watts," the circuit of Fig. 3 is set up. The field coils are connected to the secondary of the current transformer to obtain a variety of ranges. The potential circuit is connected to the load side of the current transformer primary; however it reaches the load terminals through a compensating winding "A" on the current tansformer. This winding subtracts the current drawn by the potential circuit from the gross load current and so gives true watts delivered to the load.

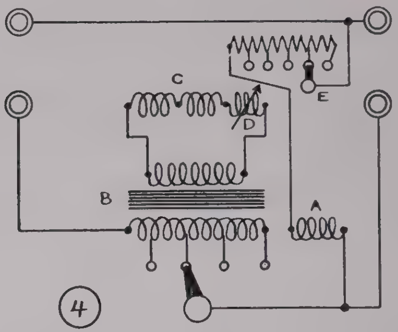


③

INTERNAL CIRCUIT WHEN MEASURING WATTS

A—Compensating Winding
B—Instrument Current Transformer
C—Dynamometer Field Coils
D—Dynamometer Moving Coil
E—Potential Circuit Resistance

Fig. 4 shows what happens when the selector switch is turned to "Amperes." The moving coil circuit is now connected in series with the field coils and they are both across the secondary of the current transformer to read current. The potential circuit is still in position across the load (a dummy resistor replaces the moving coil) and its current is still compensated out of the total current reading. Leaving the potential circuit in place although inactive, insures that the loading on the supply remains constant and does not in any way contribute to variations due to circuit switching.

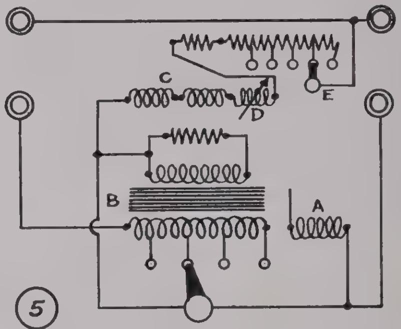


④

INTERNAL CIRCUIT WHEN MEASURING LOAD CURRENT

Note: Potential circuit is still connected across load, but its current drain is NOT included in ampere reading.

Fig. 5 is the circuit with the switch in the "volts" position. The current transformer is in active operation in order to keep the same series impedance but the secondary feeds a dummy resistance instead of the movement. The entire movement is in series with the potential circuit resistances and reads the correct value of voltage across the load.



⑤

INTERNAL CIRCUIT WHEN MEASURING LOAD VOLTAGE

NOTE: Instrument transformer is still connected in the Circuit.

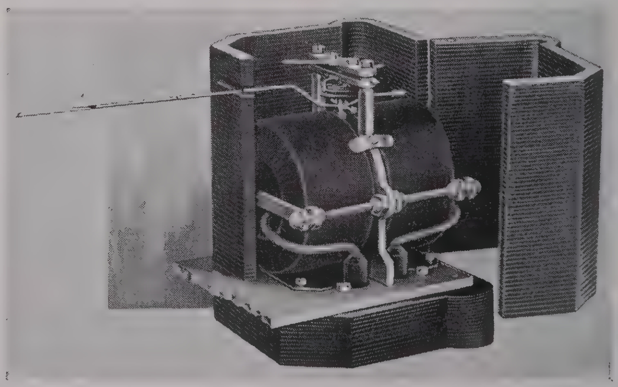
All the above circuits are controlled by internal switching which action will not cause errors in any measurement.

In all of the above operations it will be seen that the metering impedances and loads are maintained constant and the power consumed in the instrument itself is supplied by the source without being included in the load measurements.

SHIELDING—The moving coil, field windings and essential parts are completely surrounded by almost 100 high permeability laminations, each lamination being electrically insulated from each other.

This shielding system effectually shields the coil from external magnetic fields and electrostatic charges.

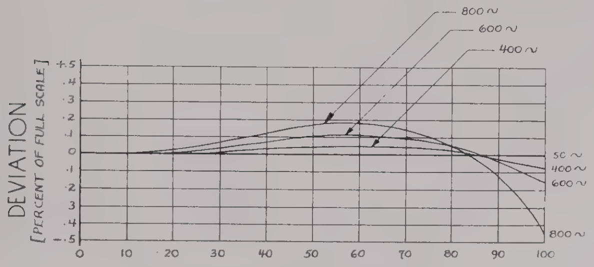
RESISTANCES—All resistances used in our instruments are of well aged double silk covered low temperature coefficient wire. The copper leads are all high temperature silver soldered, assuring a perfect constant connection which is unaffected by age, moisture or temperature changes.



UNMOUNTED MOVEMENT AND SHIELD

FREQUENCY RESPONSES AND ERRORS IN THE VOLT-AMP-WATTMETER

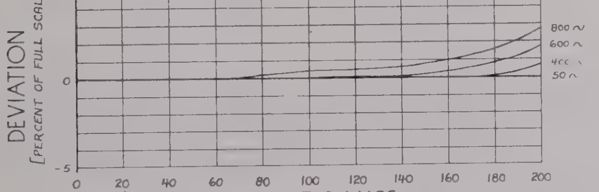
We have received many requests for information as to approximate direction and amount of the various errors which might be encountered in the use of the "VAW" instrument at various frequencies for all types of measurement. We took a production lot of the code VOLTOWATT instrument, which is designed to operate over a frequency range of 25 to 800 cycles and made exact measurements on all of them under all combinations of frequency and range. The accompanying figures A thru E show the extremes of the errors encountered. These figures are not intended to be used for correction curves nor are they to be considered to extend the basic accuracy guarantees. However, as a general indication of trends, they are certainly of great importance.



100 VOLT RANGE

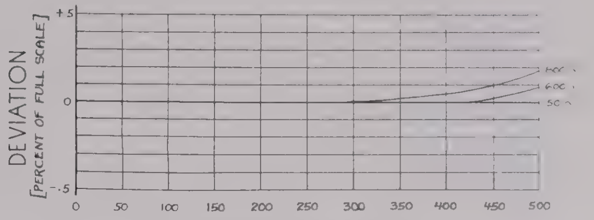
(A)

Fig. A is a plot of the lowest voltage range errors. These are plots of error vs. scale reading because in any dynamometer instrument on AC, there is of necessity an impedance variation with pointer deflection due to the variation in mutual inductance of the fields and moving coils. The frequency compensation has to be done on an average inductance basis and is perfect at only a single point. These curves represent the poorest of the group and the best instrument has approximately half of these errors. The shape of the curves is characteristic, however. Fig. B and Fig. C show errors for the higher volt ranges where the additional series R washes out most of the inductive errors.



200 VOLT RANGE

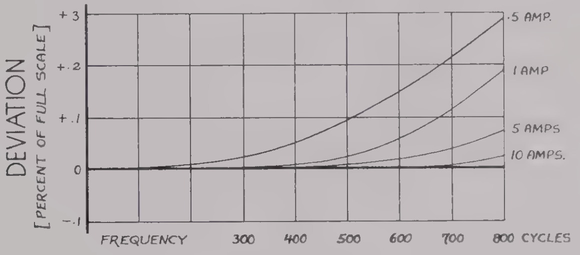
(B)



500 VOLT RANGE

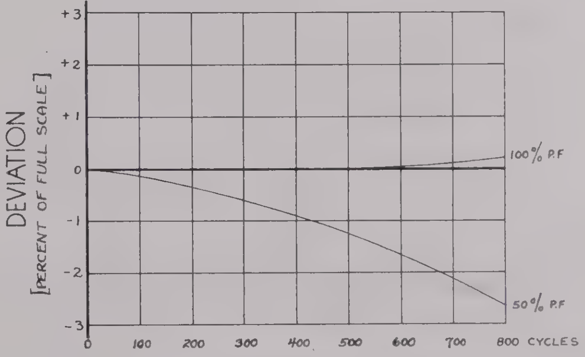
(C)

Fig. D shows plots of the various current ranges against frequency and these curves can be used for any position on the scale as the inductance variations have a negligible effect on the current readings.



CURRENT

(D)



WATTS
100 V.–1 AMP.

(E)

Fig. E shows a similar plot of wattmeter errors versus frequency. The curve labeled 100% power factor shows comparable errors with the volts and amperes curves. The scale factors are changed to accommodate the greater errors encountered. The curve marked 50% power factor shows markedly greater errors than at 100%. These errors are primarily due to phase angle errors of the current transformer. Such errors are negligible at or near zero degrees (100%) but become very significant at lower power factors. Intermediate values of power factor can be expected to produce curves intermediate to the ones for 100% and 50%.

POLYPHASE WATTMETERS

MODEL **PDW**

ACCURACY	.5 of 1%
SCALE	6.3"
FREQUENCY	To 800 cycles
SIZE	8½"x7¾"x7½"
WEIGHT	10½ lbs.
TYPE	Dynamometer

HORIZONTAL

SUPPLIED WITH DIAMOND PIVOTS
AND SHOCK MOUNTED JEWELS

Listed below are standard ranges for Polyphase (two element) wattmeters. ANY polyphase instrument will indicate full scale for ANY of these combinations of rated power.

1. Three phase power in any combination of loading, balanced or unbalanced.
2. Single phase power applied to EITHER phase A circuits OR phase B circuits, not both.
3. The SUM of single phase powers being fed to phase A and phase B circuits simultaneously.
4. Two phase power fed to phase A and phase B circuits.

THREE RANGE

FULL SCALE WATTS		NORMAL (Unity P. F.) FIELD CURRENT PER PHASE		MAXIMUM (50% P.F.) FIELD CURRENT PER PHASE		(OVERLOAD 60%) VOLTS		Code Word	Price
Low Volts	High Volts	Series	Parallel	Series	Parallel	Low	High		
15/30	30/60	.075 A.	.15 A.	.15 A.	.3 A.	100	200	PDWAMIS	$550.00
25/50	50/100	.125	.25	.25	.5	100	200	PDWANOT	550.00
37.5/75	75/150	.1875	.375	.375	.75	100	200	PDWYFAT	550.00
75/150	150/300	.375	.75	.75	1.5	100	200	PDWASUL	550.00
125/250	250/500	.625	1.25	1.25	2.5	100	200	PDWARAB	550.00
150/300	300/600	.75	1.5	1.5	3.0	100	200	PDWHACK	565.00
250/500	500/1000	1.25	2.5	2.5	5.0	100	200	PDWASED	570.00
300/600	600/1.2 k.w.	1.5	3.0	3.0	6.0	100	200	PDWAHLN	570.00

Any of the above ranges available with the voltage increased to 110-220 volts at no additional cost. Watt ranges will remain the same, but field current will change. Use the above code word, adding the letter "s."

Potential circuits vary from 100 to 333 ohms per volt.

FOUR RANGE WATTMETER

FULL SCALE WATTS			NORMAL FIELD CURRENT PER PHASE		MAXIMUM FIELD CURRENT PER PHASE		(OVERLOAD 60%) VOLTS			Code Word	Price
Low Volts	Medium Volts	High Volts					Low	Medium	High		
15/30	30/60	60/120	.15 A.	.3 A.	.3 A.	.6 A.	50	100	200	PDWEAPA	$565.00
25/50	50/100	100/200	.25	.5	.5	1.0	50	100	200	PDWEALM	565.00
50/100	100/200	200/400	.5	1.0	1.0	2.0	50	100	200	PDWEAZO	565.00
75/150	150/300	300/600	.75	1.5	1.5	3.0	50	100	200	PDWEAEN	580.00
125/250	250/500	500/1000	1.25	2.5	2.5	5.0	50	100	200	PDWEAFE	585.00
250/500	500/1000	1000/2000	2.5	5.0	5.0	10.0	50	100	200	PDWEAGZ	585.00

Any of the above ranges available with the voltage increased to 110-220-440 volts at no additional cost. Use the above code word adding the letter "s." Watt ranges will remain the same but field current will change.

Our POLYPHASE WATTMETERS are also supplied in an edgewise panel mounted case. This aluminum case is called PDWEW-5 and its scale length is 5.2". All other specifications are similar to portable Model PDW. The addition of the letters EW to PDW means supplied in an edgewise panel case. Add $50 to price.

POLYPHASE POWER MEASUREMENTS:

Two and three phase power measurements can be made in many different ways with SENSITIVE RESEARCH Wattmeters. Any ranges of our standard single phase wattmeters can be furnished with "Y" boxes for the measurement of three phase power in cases where the load is balanced. "Y" boxes must be ordered with the instrument with which they are to be used. If ordered at a later date the instrument serial number must be given and the box is restricted to use with that specific instrument. For polyphase power measurements without limitation of requiring a balanced load SENSITIVE RESEARCH Polyphase Wattmeters offer the most satisfactory solution. These instruments, which are essentially two complete wattmeters on a common shaft are furnished in both the standard 50% P.F. type and also in a 20% P.F. instrument. For those applications, where the meter circuit itself will appreciably unbalance the load voltages, compensating inductors can be furnished for the third leg. These inductors have identical resistance and inductance to the field circuits of the wattmeters with which they are to be used. Compensating inductors must be ordered with the instrument or the serial number of the instrument furnished and their use is restricted to that individual instrument.

MODEL **PDLW**

ACCURACY	.75 of 1%
SCALE	5.2"
FREQUENCY	To 500 cycles
SIZE	8½"x7¾"x7½"
WEIGHT	10½ lbs.
TYPE	Dynamometer

HORIZONTAL

USE ONLY

For Model EW-5 deep (5.2" scale) panel mounted case, add $50.00 to prices listed below.

CURRENT COILS RATED FOR USE AT
LOW POWER FACTOR DOWN TO 20%

CAN BE USED ON D.C. AND A.C. UP TO
500 CYCLES WITHOUT CORRECTIONS

The wattmeters listed below are for use on power factors down to 20%. In special cases we can supply them for use on power factors down to 10% or at frequencies up to 2500 cycles. Correspondence invited.

Due to our large experience with precision wattmeters over the past 32 years, we invite inquiries on special wattmeter problems.

DIAMOND PIVOTS AND SHOCK MOUNTED JEWELS USED ON THIS INSTRUMENT.

THREE RANGE WATTMETERS

FULL SCALE WATTS		NORMAL (Unity P. F.) FIELD CURRENT PER PHASE		MAXIMUM (20% P. F.) FIELD CURRENT PER PHASE		(OVERLOAD 60%) VOLTS			
Low Volts	High Volts	Series	Parallel	Series	Parallel	Low	High	Code Word	Price
1.5/3	3/6	.01 A.	.02 A.	.05 A.	.1 A.	75	150	PDLWAMOS	$665.00
5/10	10/20	.033 A.	.066 A.	.166 A.	.33 A.	75	150	PDLWAKOR	625.00
7.5/15	15/30	.05 A.	.1 A.	.25 A.	.5 A.	75	150	PDLWACOT	625.00
10/20	20/40	.066 A.	.133 A.	.333 A.	.666 A.	75	150	PDLWAROT	625.00
15/30	30/60	.1 A.	.2 A.	.5 A.	1. A.	75	150	PDLWACUM	625.00
20/40	40/80	.133 A.	.266 A.	.66 A.	1.33 A.	75	150	PDLWAPOT	625.00
37.5/75	75/150	.25 A.	.5 A.	1.25 A.	2.5 A.	75	150	PDLWAKER	635.00
75/150	150/300	.5 A.	1.0 A.	2.5 A.	5. A.	75	150	PDLWAKIT	645.00
150/300	300/600	1. A.	2. A.	5. A.	10. A.	75	150	PDLWARUS	660.00
300/600	600/1200	2. A.	4. A.	10. A.	20. A.	75	150	PDLWAAST	685.00

Any of the above ranges available with the voltage increased to 110-220 volts at no additional cost. Watt ranges will remain the same, but field current will change. Use the above code word, adding the letter "s."

Potential circuits have a resistance of from 100 to 350 ohms per volt.

FOUR RANGE WATTMETERS

FULL SCALE WATTS			UNITY P. F. FIELD CURRENT PER PHASE		20% P. F. FIELD CURRENT PER PHASE		(OVERLOAD 60%) VOLTS				
Low Volts	Medium Volts	High Volts	Series	Parallel	Series	Parallel	Low	Medium	High	Code Word	Price
1.5/3	3/6	6/12	.01 A.	.02 A.	.05 A.	.1 A.	75	150	300	PDLWATOS	$680.00
5/10	10/20	20/40	.033 A.	.066 A.	.166 A.	.333 A.	75	150	300	PDLWATUF	640.00
15/30	30/60	60/120	.1 A.	.2 A.	.5 A.	1. A.	75	150	300	PDLWATYI	640.00
20/40	40/80	80/160	.133 A.	.266 A.	.666 A.	1.33 A.	75	150	300	PDLWATKO	640.00
37.5/75	75/150	150/300	.25 A.	.5 A.	1.25 A.	2.5 A.	75	150	300	PDLWATSA	650.00
75/150	150/300	300/600	.5 A.	1. A.	2.5 A.	5. A.	75	150	300	PDLWATTI	660.00
150/300	300/600	600/1.2 k.w.	1. A.	2. A	5. A.	10. A.	75	150	300	PDLWATBA	675.00
300/600	600/1.2	1.2/2.4 k.w.	2. A.	4. A.	10. A.	20. A.	75	150	300	PDLWATFO	700.00

Any of the above ranges available with the voltage increased to 110-220-440 volts at no additional cost. Use the above code word adding the letter "s." Watt ranges will remain the same but field current will change.

"SENSITIVE RESEARCH" FIELD ENGINEERING REPRESENTATIVES

HOME OFFICE
310 MAIN ST., NEW ROCHELLE, N. Y.
BEverly 5-2300

EARL LIPSCOMB ASSOCIATES
TRAVELAB
ELECTRONIC INSTRUMENTS

TYPICAL INTERIOR

EXPORT

AD. AURIEMA, INC.
85 Broad Street
New York 4, New York
Bowling Green 9-7750

EASTERN CANADA

MEL SALES LTD.
Arnprior, Ontario, Canada
Arnprior 400

P.O. Box 50, Don Mills
Toronto, Ontario
Hudson 1-0231

P.O. Box 1352, Postal Sta. "O"
Montreal, Quebec
St. Eustache 9198

WESTERN CANADA

ARVA, Inc.
Room 7— Marine Bldg.
355 Burrad Street
Vancouver 1, B.C., Canada
Mutual 1-3367

N. & S. CAROLINA — S. VIRGINIA

J. L. HIGHSMITH & CO.
737 Providence Rd.
Charlotte, North Carolina
Franklin 7-2546

CALIFORNIA, ARIZONA, NEVADA

McCARTHY ASSOCIATES
1055 East Walnut
Pasadena, California
Sycamore 2-8272

934 West Laurel Street
San Diego, California
Belmont 9-4015

635 Oak Grove Avenue
Menlo Park, California
Davenport 6-7937

GEORGIA, KENTUCKY, TENNESSEE, and ALABAMA

BIVINS & CALDWELL
3133 Maple Dr., N.E.
Atlanta 5, Georgia
Cedar 3-7522

Huntsville, Alabama
Jefferson 2-5733
(Direct line to Atlanta office)

FLORIDA

ARTHUR H. LYNCH AND ASSOCIATES

35 W. North Shore Ave.
Fort Myers, Florida
Wyandotte 5-2151

P.O. Box 2492
Gainesville, Florida
Franklin 2-8028

NO. ILLINOIS and SO. WISCONSIN

SAFFRO & GETTLEMAN CO.
5209 No. Kimball Avenue
Chicago 25, Illinois
Juniper 8-0905

INDIANA

LAW INSTRUMENT COMPANY
P. O. Box 95
Angola, Indiana
217 & 8101-R

P.O. Box 6562
Indianapolis 27, Indiana
State 7-0009

KANSAS, WESTERN MISSOURI

HARRIS-HANSON COMPANY
7916 Paseo Avenue
Kansas City 30, Mo.
Hiland 4-9494

EASTERN MISSOURI, SOUTHERN ILLINOIS

HARRIS-HANSON COMPANY
2814 South Brentwood Blvd.
St. Louis 17, Mo.
Mission 7-4350

MICHIGAN

S. STERLING COMPANY
15310 W. McNichols Road
Detroit 35, Michigan
Broadway 3-2900

OHIO

S. STERLING COMPANY
5827 Mayfield Road
Cleveland 24, Ohio
Hillcrest 2-8080

MINNESOTA, IOWA, NEBRASKA
N. & S. DAKOTA, NO. WISCONSIN

THE HEIMANN COMPANY
1711 Hawthorne Avenue
Minneapolis 3, Minnesota
Federal 2-5457

NEW MEXICO

GENE FRENCH COMPANY
120 San Pedro Drive S.E.
Albuquerque, New Mexico
Amherst 8-2478

PHILADELPHIA, EASTERN PENNA. & SOUTH NEW JERSEY

I. E. ROBINSON (Main Branch)
7404 West Chester Pike
Upper Darby, Penna.
Sherwood 8-1294

2120 Market St.
Camp Hill, Penna.
Regent 7-6791

905 Main St.
Asbury Park, New Jersey
Kellog 1-3150

CENTRAL NEW YORK

J. F. WULFETANGE, JR.
4505 E. Genesee St.
De Witt 14, New York
Gibson 6-3330

WESTERN NEW YORK

THE ROBERT F. LAMB CO.
1807 Elmwood Avenue
Buffalo 7, New York
Bedford 3757

NEW ENGLAND AND EASTERN N. Y.

YEWELL ASSOCIATES, INC.
Middlesex Turnpike
Burlington, Mass.
Browning 2-9000

1101 E. Main Street
Bridgeport, Conn.
Forest 6-3456

OREGON, WASHINGTON, IDAHO
W MONTANA, HAWAII & ALASKA

ARVA, Inc.
120 West Thomas Street
Seattle 99, Washington
Atwater 4-7337

1238 N.W. Glisan
Portland 9, Oregon
CApitol 7-1281

PITTSBURGH, W. PA. AND W. VA.

S. STERLING COMPANY
4024 Clairton Blvd.
Pittsburgh 27, Penna.
Tuxedo 4-5515

TEXAS

EARL LIPSCOMB ASSOCIATES
P. O. Box 7084
Dallas, Texas
Fleetwood 7-1881

UTAH, COLORADO, WYOMING
& E. MONTANA

LAHANA AND COMPANY
1886 South Broadway
Denver 10, Colorado
Pearl 3-3791

WASHINGTON, D. C., MD. AND DEL.

HORMAN ASSOCIATES, INC.
941 Rollins Avenue
Rockville, Maryland
Hazelwood 7-7560

3006 West Cold Spring Lane
Baltimore 15, Maryland
Mohawk 4-8345

Second Printing

Prices and specifications subject to change without notice.

Electrical MEASUREMENTS

JAN 1 1959

VOLUME 25 MAY 1958 NUMBER 5

THERMO COUPLES AND THERMO COUPLE INSTRUMENTS

VOLTS RF SWITCH
SENSITIVE RESEARCH INSTRUMENT CORPORATION
NEW ROCHELLE NEW YORK
VOLTS
SENSITIVE RESEARCH
Radio Frequency VOLTMETER

MODEL RFV

SENSITIVE RESEARCH INSTRUMENT CORPORATION

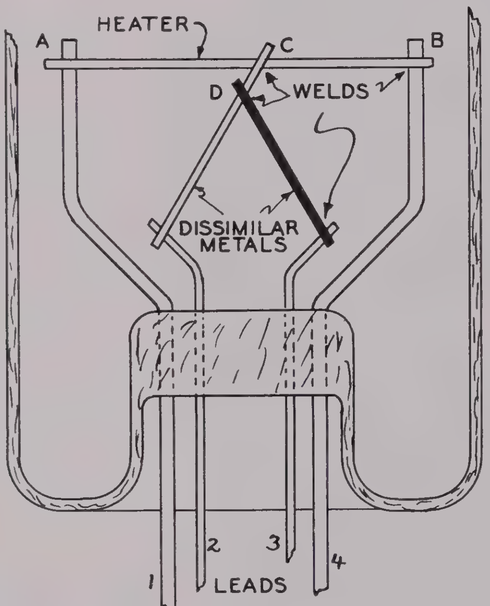
NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

Symbol of Quality

Of all the commonly used electrical measurement equipment in the ordinary laboratory, the thermocouple is probably the most controversial. Engineers have very definite opinions about such instruments. In fact, it would seem that they might have more opinions than knowledge of it. These opinions vary from the "I can't keep couples in the instrument" of the inexperienced, to the "I couldn't possibly get the correct measurement any other way" of the engineer who is thoroughly familiar with both their limitations and their many advantages.

Even the name thermocouple instrument is subject to considerable discussion to say the least. The oldtimer in speaking of a vacuum thermocouple refers to a resistance mounted in vacuum with a junction of two dissimilar metals attached to this heater to develop a voltage proportional to the temperature of the resistance. This has lately been referred to as a thermo-element instead. This designation in some way helps to differentiate between this type unit and the thermal junction alone used to measure temperatures. As far as these writings are concerned by thermocouple we refer to an electrically heated thermal junction used with a D.C. instrument as a means of measuring the current flowing through the heater.

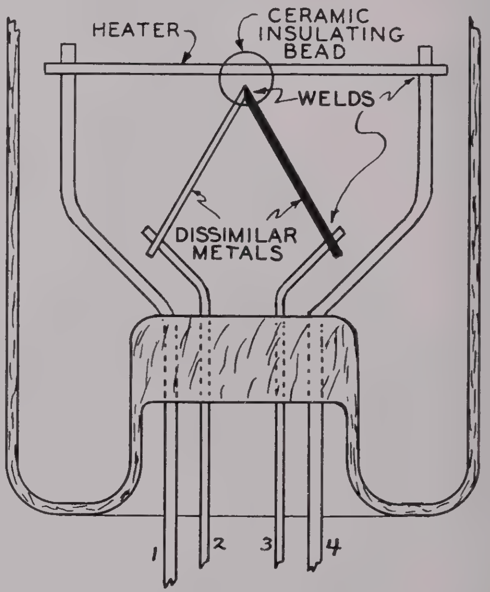


CONTACT HEATER THERMO-COUPLE ①

In fig. I is shown the internal construction of the usual vacuum thermocouple. The current to be measured is introduced by means of leads 1 and 4. The current flows through the heater wire which is welded to these leads at points A and B. The current flow through this heater wire (which is made of high resistance material) causes the heater to rise in temperature because of the $I^2 R$ losses in its resistance. Welded to the center of the heater (the hottest point because of cooling effect of the lead-in wires) is a thermal junction composed of two dissimilar metals which have a high thermoelectrical potential.

Rated current through the heater will raise the temperature of the junction point to about 300 deg. C. and this temperature will produce ten to twelve millivolts open circuit EMF in the average SRIC vacuum couple (the guaranteed minimum value, 7 millivolts). The EMF developed in the junction is used to operate a D.C. millivoltmeter which is in turn calibrated on its scale in terms of the current supplied to the heater.

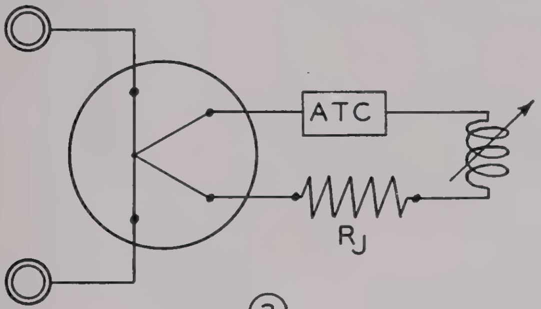
The combination just described is a means of providing A.C. measurements with a mechanism responsive to D.C. only. As such, it has several inherent advantages that are shared by NO OTHER means of A.C. measurement. The meter deflection is directly proportional to heater temperature and hence, because temperature is proportional to the square of the current through the heater, the meter indication will be a true RMS measure of the heater current. The current being measured is passed through a resistance which is substantially independent of frequency and so the accuracy of indication can be considered independent of frequency. The heater wires are of very fine, high resistance material and hence do not change resistance except at very high frequencies. The inductance of the leads and the capacity between leads at the seal are the only other appreciable factors in the frequency response of a vacuum thermocouple and these are very small values.



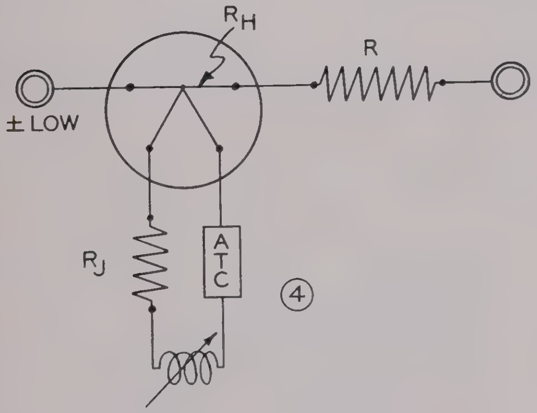
INSULATED HEATER THERMO-COUPLE ②

The combined effect of all these factors will be under .5 of 1% from DC to over 10 megacycles. In order to keep the DC instrument's movement from adding markedly to the capacitance of the couple and any associated circuits the construction of the thermocouple shown in Fig. 2 is used. In this type of construction the actual thermal junction is in thermal contact with the heater but is electrically insulated from it by a small bead. This introduces a very small capacitance in series with anything connected to the junction circuit and thus tends to minimize the capacity effect of this circuit. All SENSITIVE RESEARCH vacuum thermocouples are available in this insulated type and their use is recommended for high frequency applications.

The vacuum thermocouple is available with rated current values of 1.5 milliamperes up to one ampere. For current measurements the circuit of Fig. 3 is used. The current to be measured flowing through the heater is indicated by the DC movement. Calibration is adjusted by means of the series resistance R_J and in SENSITIVE RESEARCH instruments an automatic temperature compensation circuit is also included to obtain a constant output over a range of temperatures of 20 to 30 degrees C.

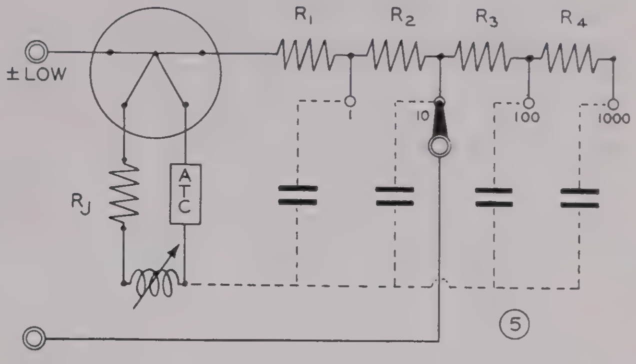


③



④

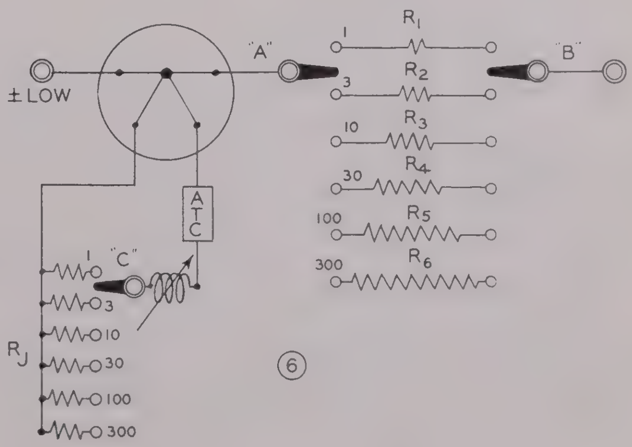
Adding series resistance to the heater circuit as shown in Fig. 4 will allow calibration to be in terms of applied voltage instead of heater current. At frequencies, which the thermocouple is capable of operating, the limiting factor becomes the characteristics of the resistors and wiring. This is particularly true in the case of a multirange voltmeter as shown in Fig. 5. In bringing the various resistor taps to a common point for switching, a certain amount of capacitance is unavoidable. This capacitance is of a rather complicated nature, but in Fig. 5 we have shown only ONE of the major paths. If we make the reasonable assumption that the capacitances from each of the switch contacts are equal, we will have a condition in which each contact has a time constant RC. The C's will all be equal and the R's in proportion to the voltage of the taps. This condition then will cause progressively larger errors as the switch is turned to the higher voltages. This is the usual type of frequency error, and most multirange instruments will be much broader in frequency response on their lower ranges than they are at the highest range (assuming that we are talking about the readings within the guaranteed accuracy of the instrument).



⑤

One method of minimizing the frequency errors encountered in multirange instruments is shown in Fig. 6. This is the basic circuit of our SENSITIVE RESEARCH Model RFV RADIO FREQUENCY VOLTMETER. In this type of instrument the switching is done by means of three mechanically ganged switches that are physically WIDELY SEPARATED. A and B switches serve to change ranges but it will be noticed that only the resistor in use is connected into the circuit, there are no capacitances from the unused sections of resistance or leads. This method of switching itself results in markedly lower capacities. In addition the resistors in the RFV instrument are of the evaporated metal film type instead of the usual wire wound type. Because the metal film, (although it has superior frequency characteristics), is difficult to adjust to high accuracy a third switch is used (section C) to provide the necessary fine calibration adjustment in the DC portion of the instrument. With this type of instrument errors of under .5 of 1% at frequencies of up to 2 mc. are attainable.

The preceding information informs that a properly designed thermocouple instrument has a wide frequency range, high sensitivity and a true RMS response. All of these are unques-



⑥

tionably highly desirable characteristics for an AC instrument. In addition it is a very satisfactory AC-DC transfer standard. It can be certified on DC with their easily obtainable high accuracy standards and then used with certainty to make AC measurements up to very high frequencies.

In this respect it would be well to look back to Fig. 1 and to note the method of attaching the junction to the heater. If the two junction wires and the heater were all welded at a single common point it is certain that there would be at least some common area and the flow of current through this area would cause a voltage drop which would be added into the junction circuit. On AC this would be of negligible importance, but on DC this EMF caused by voltage drop rather than thermoelectric effect would in one direction add to the output and in the other direction subtract from the output. This is the cause of DC reversal effects. This source of error is minimized by the type of construction shown in Fig. 1. Here there is NO heater current through the actual junction, although the junction is in good thermal contact with the heater. DC reversal readings will not vary more than 0.2% with this type of construction. In carefully selected insulated bead type couples this DC error on reversal can be as little as .01%.

Having shown that the thermocouple can very well be of great help to the engineer requiring a high sensitivity, high frequency instrument let us also look at what we have to pay for it in compromises. These limitations occasionally bring on the "creation of the devil" feeling about such instruments. A little real understanding of the thermocouple will eliminate this feeling altogether.

At normal rated current the heater reaches a temperature of about 300 deg. C. to provide the thermal EMF for its output. If we now double this current the temperature is going to go, not to 600 deg. but to 1200 deg. C. because the wattage dissipated in the heater varies as square of the current. Actually it would not quite reach 1200 deg. as radiation losses increase as the fourth power of Kelvin degrees and tend to bring it down somewhat. However, the heater does reach a temperature of nearly 1200 degrees and is obviously dangerously close to the burn-out point because of the heater possibly melting. This feature which gives the instrument because of square law, true RMS response, is also its downfall as being temperature operated it reaches a burn-out point at a SQUARE LAW RATE. Obviously, then it is imperative to operate a thermocouple in a fashion that will protect it against overloads of more than about twice its rated heater current.

Even consideration of the above paragraph does not tell us all the knowhow we need to satisfactorily use thermocouples. We have become accustomed to think of overload in terms of time to blow fuses. The ordinary fuse will stand a momentary overload of many times its rated current due to a definite thermal lag in reaching the steady state temperature. This unfortunately is not true in a vacuum thermocouple. The heater is in a vacuum enclosure and supported by relatively low thermal conductivity supports. It is made of very fine wire for its normal rating is such that it is INTENDED to get hot at a rated current. All this means that the heater will follow at a very rapid rate the square law temperature. This gives rise to the oft heard "I didn't burn it out, the pointer didn't get off the scale." Fig. 7 will show how faulty this reasoning can be.

Fig. 7 is a plot against time of the current through the heater, the temperature of the heater and the pointer deflection. The total time shown on the graph is very short, a few tenths of a second. The current rises at a very rapid rate due to some transient in the circuit. The temperature rises at a rate which tries to follow the square law temperature characteristic. It cannot quite reach this rate of rise due to its thermal mass, but because of the near ideal surroundings in which it exists it does rise at a very sharp rate to burn-out due to the heater melting at time T_1. Now look at the instrument deflection curve. The

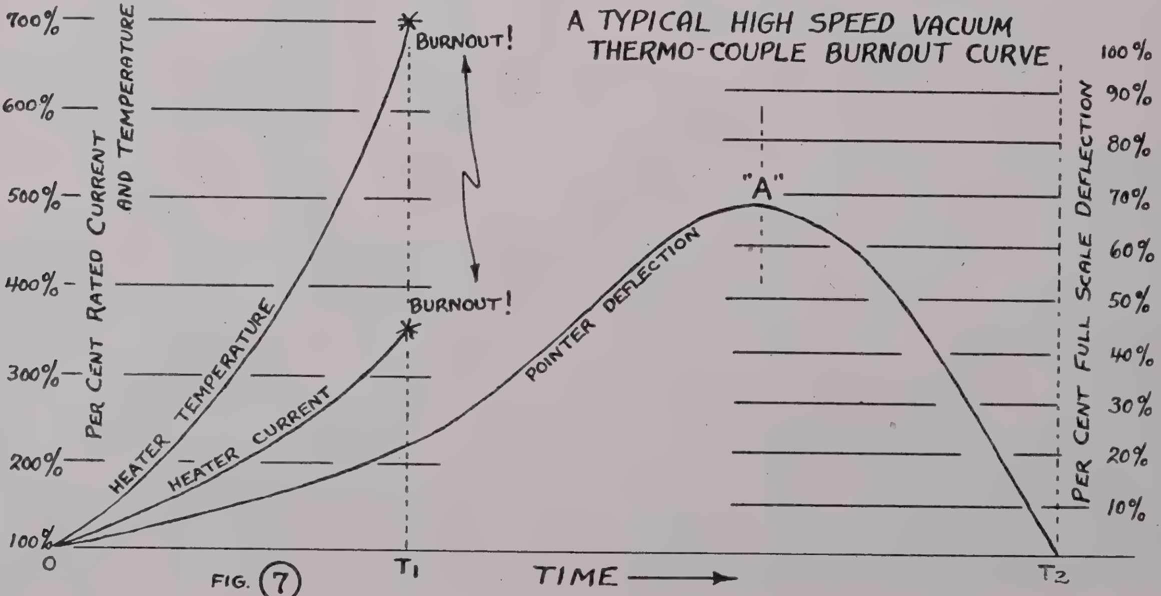


FIG. ⑦

torque applied to the movement will be directly and linearly proportional to the temperature curve. But the movement in a thermal instrument is heavily damped because of the low resistance of the junction circuit and its own inherent sluggishness due to its high sensitivity. The pointer will follow the rising temperature curve but with a relatively large time lag. At the moment of actual burn-out the pointer will have reached only a very small deflection. Due to thermal capacity in the junction and the melted heater some torque will remain for a slight interval and some energy will be stored in the movement itself as kinetic energy due to its motion. These factors will cause the pointer to continue on up scale for a slight period of time AFTER ACTUAL BURN-OUT but will often be insufficient to ever reach full scale and the pointer will drop back without ever actually reaching the full scale point. The lesson to be learned is "A FAST TRANSIENT CAN CAUSE THERMOCOUPLE BURN-OUT WHETHER OR NOT THE INSTRUMENT EVER INDICATES AN OVERLOAD." You cannot depend on the instrument to protect itself or even to show you when it needs protection. It is imperative that possible sources of such transients be considered in the circuits in which thermocouples are to be used. Any inductance or capacitance in which energy CAN BE STORED AND DISCHARGED into the circuit as a transient must be carefully considered when using vacuum thermocouples.

Vacuum thermocouples are, in general, used for ranges up to approximately one (1) ampere. Beyond this range ordinarily an air couple is used. The construction of air couples is electrically very similar to the vacuum couples we have described. They have a heater and junction combination differing only in the fact that it is not placed in an evacuated bulb. A decrease in sensitivity does result because of the conduction of heat away from the heater by the surrounding air. At these higher currents (above 1 ampere) we ordinarily have extra power available and the air type construction is permissable. Because these couples carry higher current the physical form is changed to allow heavy lead connections, see photo below.

The connection terminals of air couples are made large and of high thermal conductivity to insure a large thermally stable "heat sink." Compensation for cold junction temperature is obtained by making the cold junctions thermally attached to the connection blocks even though electrically insulated. This effectively eliminates drift with temperature, either ambient or self heat effects.

The heater element in the heavy current (1 amp to 100 amp, Model XT) units is a single straight resistance made of light gauge material. The inductive and capacity errors are of negligible magnitude and because of the high specific resistance of the material used the skin effect is also negligible. Our Model XT Instruments have negligible frequency errors (under ½%) up to at least 70 megacycles for ranges from 1 to 10 amperes and to at least 20 megacycles for 20 to 100 ampere couples.

These heavy current thermocouples are extremely useful for radio frequency measurements of antenna current, tank circuit currents and similar high RF currents. The true RMS readings with very low insertion losses cause them to be universally used for such measurements. Accuracy can always be checked on DC test equipment by taking the mean of reversed DC readings. Heavy current air couples cannot be furnished in the insulated type, however this is seldom a limitation at these power levels.

HEAVY CURRENT THERMO COUPLE AMMETERS

MODEL XT

FOR D.C. OR A.C. MEASUREMENTS

FITTED WITH DIAMOND PIVOTS

AUTOMATIC TEMPERATURE COMPENSATED!

ACCURACY	1%
SCALE	6.3"
FREQUENCY	To 70 megacycles
SIZE	8 "x7½"x4½"
WEIGHT	7 lbs.
TYPE	Thermocouple

MAGNETICALLY SHIELDED

These instruments are guaranteed to be within 1% up to 70 megacycles. They can be checked on direct current and have no wave form error. The instruments are characterized by a very stable zero and freedom from ambient temperature errors. They are similar in appearance to our Model A milliammeters, scale length 6.3 inches, see next page, with the exception that the thermocouples are mounted as a unit on the side of the instrument case.

Full Scale Amperes	Lowest Reading	Code	Price
2	.4 Amps.	TALEM	$267.00
5	1 Amps.	TASIS	267.00
10	2 Amps.	TAMOR	270.00
* 20	4 Amps.	TAKIM	278.00
* 30	6 Amps.	TAFOR	285.00
* 50	10 Amps.	TABEL	297.00
*100	20 Amps.	TACZX	442.00

*D.C. and A.C. up to 20 m.c.

USE OF MILLIVOLTMETERS WITH EXTERNAL THERMOCOUPLES

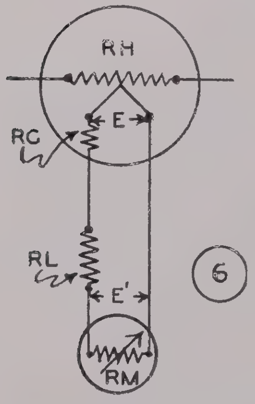
Frequently it becomes desirable to use an available separate thermocouple and millivoltmeter for temporary measurements rather than obtaining a suitable range in a complete self-contained instrument. This can be readily done by reference to the catalogue information given for the couples and millivoltmeters separately. (Catalog #70.)

One common error in the selecting of instruments for use with thermocouples is in the use of the "open circuit millivolts" listing for the thermocouple. This rating is given on the basis of the open circuit voltage output of the thermal junction when the heater is carrying rated current. This is NOT to be taken as the range of a millivoltmeter to be used for full scale deflection, because normal types of millivoltmeters draw some current. In Fig. 6, a millivoltmeter with an internal resistance "RM," is connected to a vacuum thermocouple. The voltage "E" (open circuit millivolts listing) will not be the external voltage "E'" which actuates the meter because of the IR drops in the internal resistance of the junction circuit itself, the series resistance and in the instrument.

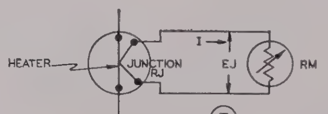
In thermocouples having heater currents from 1 milliampere to 1 ampere, the junction resistance varies from approximately 5 to 15 ohms. We therefore recommend for average measurements a 10-ohm, 200-microampere, 2-millivolt instrument (our code SMVPU) for use with any of these thermocouples. This has been a standard instrument with us for many years and has proved very successful for thermocouple use, Catalog page 77.

It can be shown that we have the most efficient operation when the resistance of the millivoltmeter equals the resistance of the junction. For this condition we have maximum power transfer. Looking at the following circuit in Fig. 7 we have the following parameters.

R_J = Resistance of the junction itself
E_J = EMF developed by couple
I = Current flowing in the circuit
R_M = Millivoltmeter resistance
P_M = Power dissipated in millivoltmeter



⑥



⑦

$$I = \frac{E_J}{R_J + R_M}$$

$$P_M = I^2 R_M = \frac{E_J{}^2}{(R_J + R_M)^2} \times R_M$$

Differentiating P_M with respect to R_M and setting the resultant equation equal to zero, we can solve for the value of RM which gives maximum power transfer.

$$\frac{dP_M}{dR_M} = [E_J]^2 \left(\frac{(R_J + R_M)^2 - 2R_M (R_J + R_M)}{(R_J + R_M)^4} \right) = 0$$

$$[E_J]^2 \left(\frac{(R_J + R_M)^2 - 2R_M (R_J + R_M)}{(R_J + R_M)^4} \right) = 0$$

$$(R_J + R_M)^2 - 2R_M \quad (R_J + R_M) = 0$$

$$R_J{}^2 + 2R_M R_J + R_M{}^2 - 2R_M R_J - 2R_M{}^2 = 0$$

$$R_J{}^2 = R_M{}^2$$

$$R_J = R_M$$

For those of you who have some odd range millivoltmeters around the laboratory and still wish to use thermocouples in conjunction with them, we recommend the following formula for determining the most appropriate millivoltmeter, the best being the one which gives the largest value for RL.

$$R_L = \frac{E\ R_M}{E'} - (R_M + R_C)$$

E' = Instrument range in millivolts
E = Open circuit millivolt rating of couple
R_M = Instrument resistance
R_C = Junction resistance (not heater res.)
R_L = Lead resistance if long leads are used *plus* any additional series resistance to give an exact full scale deflection.

The exact value of R_L cannot always be correctly calculated due to the fact that different thermocouples may have slightly different outputs. In practice the correct value of R_L should therefore be determined roughly by the above formula and most precisely by experimenting with a variable resistance box in the junction circuit with a known standard current through the heater. The variable resistance box is then adjusted to give a full scale reading for this current. The higher value of R_L is desirable because of the higher total resistance in the junction circuit, thus making it less susceptible to extraneous thermal EMF's and to resistance changes in leads and wiring. The higher series resistance also lessens the period of the instrument to some extent which is extremely desirable in thermocouple instruments since it results in faster measurements.

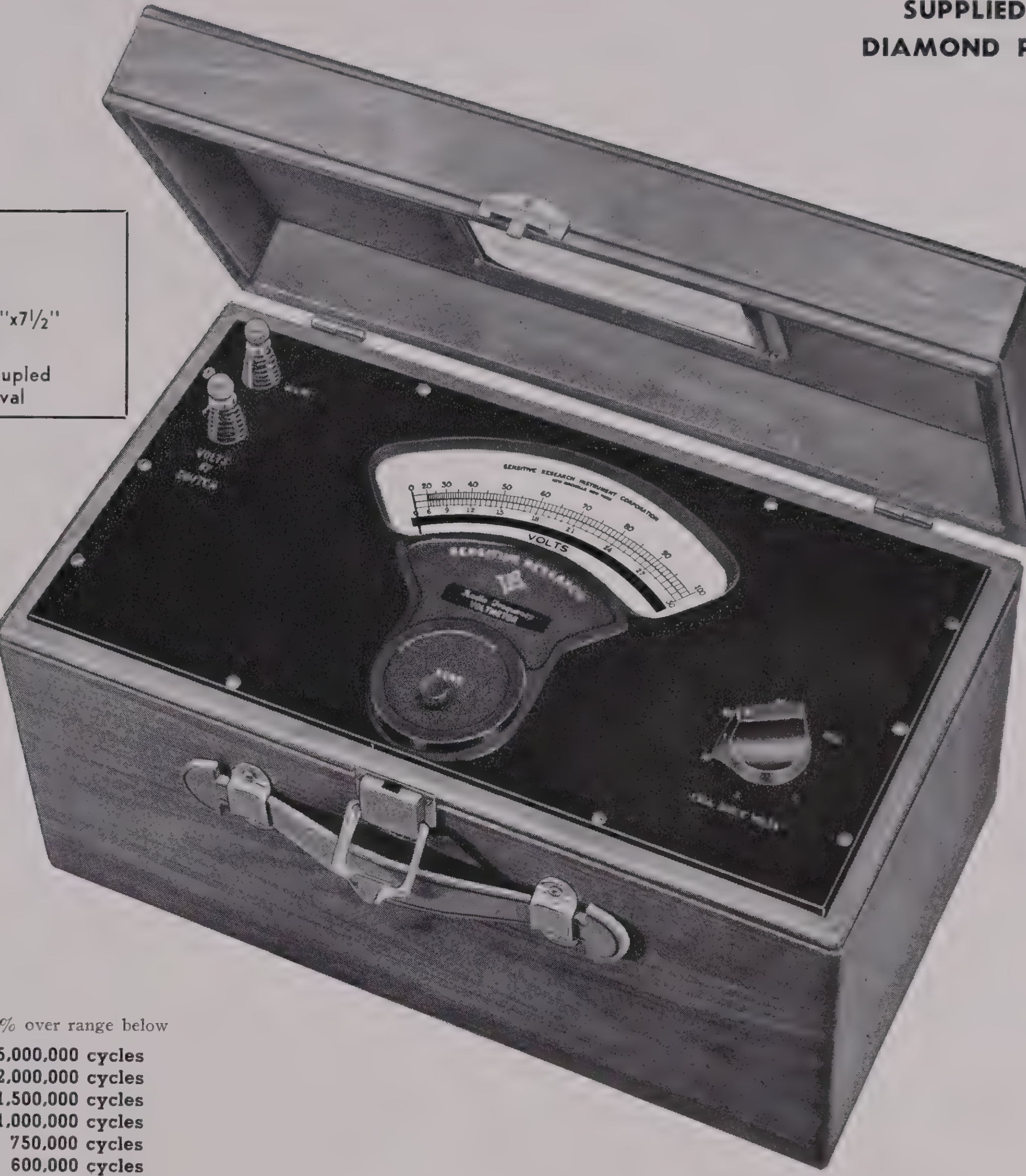
Use of an external couple and remote instrument is often desirable for high frequency measurements in order to make the AC leads short and direct. Where such installations require extra long lead lengths this must be considered in the instrument calibration and the exact lead resistance used specified.

RADIO FREQUENCY VOLTMETERS

**SUPPLIED WITH
DIAMOND PIVOTS**

ACCURACY	.5 of 1%
SCALE	6.3"
FREQUENCY	See below
SIZE	13¾"x7½"x7½"
WEIGHT	10 lbs.
TYPE	Thermo-coupled D'Arsonval

Model RFV



Frequency influence ½% over range below

1 volt	D.C. to 5,000,000 cycles
3 volts	D.C. to 2,000,000 cycles
5 volts	D.C. to 1,500,000 cycles
10 volts	D.C. to 1,000,000 cycles
15 volts	D.C. to 750,000 cycles
30 volts	D.C. to 600,000 cycles
75 volts	D.C. to 400,000 cycles
100 volts	D.C. to 200,000 cycles
300 volts	D.C. to 150,000 cycles

Sensitivity 200 ohms per volt

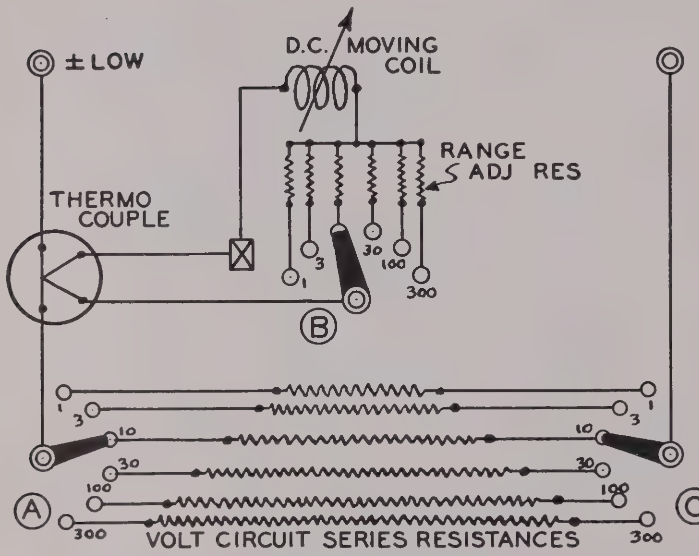
This new model "RFV" voltmeter is a high accuracy, direct reading, reference standard voltmeter, designed specifically for HIGH FREQUENCY operation. This instrument is extremely useful for the accurate checking of oscillators, signal generators and similar apparatus. It also makes a very satisfactory standard for the calibration of electronic voltmeters.

The major limitation of the usual thermocouple voltmeter occurs in the limited frequency response of the resistors used for range extension and in the distributed capacity of the switching circuits. The model RFV is free from these usual errors. The resistances used are of an extremely stable type of metallized film deposited on ceramic. Circuit capacitances have been reduced to extremely low values by means of a very special type of mechanical switching assembly, which completely isolates from the circuit, all resistances and wiring except that connected with the range in actual use. The accuracy of the individual ranges is adjusted by corrections in the DC side of an isolated heater thermocouple. This is much preferable to the usual method of adjusting the multiplier resistances by spiral grinding.

HIGH FREQUENCY AC-DC TRANSFER STANDARD

One of the very useful characteristics of the thermal instrument is its use as an AC-DC transfer standard. The Model RFV extends these characteristics up into very high frequency ranges. The use of the electrically insulated heater type of couple, in addition to giving superior high frequency performance, also reduces DC reversal effect to a negligible factor. Because of this the RFV can be standardized with a single DC reading against readily available potentiometric standards. Once so standardized the instrument if used immediately for high frequency measurement can be expected to have APPRECIABLY BETTER than rated accuracy for short periods of time. The short time stability will be comparable to the reading accuracy.

The extremely high frequency response of this instrument requires precautions in its use. It will read correctly the voltage across its terminals in true RMS values. However, connections must be short and direct or this voltage may not be the voltage really desired because of lead inductance, capacitance or pick up. This instrument has appreciable response to frequencies of beyond 100 megacycles and pick up at very high frequencies may come from very small exposed areas.



SWITCHES A-B-C OPERATE TOGETHER

☒ =TEMPERATURE COMPENSATION

BASIC VOLTMETER CIRCUITS

Frequencies at .5 of 1% Accuracy

The frequency response of the Model RFV varies with the range in use. On the highest available range, (300 volts) the instrument has an accuracy of ½% from D.C. to 150,000 cycles. The 100 volt range can be used up to 500,000 cycles. Lower voltage ranges have a proportionally higher frequency response with the lowest available range (1 volt) being good to 5 megacycles. The sensitivity on all ranges is approximately 200 ohms per volt.

AUTOMATIC TEMPERATURE COMPENSATION

By the use of an automatic temperature compensation network, the usual temperature coefficient of this thermocouple instrument is reduced to a value so low that NO temperature correction need be applied when the ambient temperature varies from 20°C. to 30°C. Outside this range of temperatures there is a very small temperature coefficient. The proper temperature correction information is supplied with each instrument on its data card in the instrument cover.

This is a distinct advantage in using SRIC thermocouple instruments.

The listed ranges overlap each other and its scale length of 6.3 inches is easily read.

Full Scale Volts	Lowest Calibrated Point	Code Word	Price
1/3/10/30/100/300 v.	.2 volt	RFVOLT	$493.00
1/2/5/10/20/50 v.	.2 volt	RFVATS	470.00
1.5/3/7.5/15/30/75 v.	.3 volt	RFVEEK	470.00
5/10/20/50/100/200 v.	1. volt	RFVIOZ	478.00
7.5/15/30/75/150/300 v.	1.5 volts	RFVYOX	483.00

◆

For over 25 years we have published this company bulletin "ELECTRICAL MEASUREMENTS." In it we describe new instruments and measurement techniques. It is sent without cost to interested persons. If you have not been receiving this publication, please advise "SENSITIVE RESEARCH."

SENSITIVE RESEARCH INSTRUMENT CORPORATION

A BROCHURE OF
ELECTRICAL MEASURING STANDARDS

"COMMANDER" INSTRUMENT INDEX AND PRICE LIST NO. 101-60

PAGE NO.	DESCRIPTION	TYPE NO.	PRICE*
1	**DC Potentiometer** (Dauphinee)	9144	$5285
2	DC Potentiometer	4363D	3133
2	DC Potentiometer (Diesselhorst) See Note A at bottom of page	3589S	2607
3	DC Potentiometer	4363A	1980
3	DC Potentiometer	4025	1268
3	**Direct Reading Thermometer Bridge**	9500	7641
4	**Multiple Standard Resistor**	9200	423
4	4 Terminal Standard Resistor (all values)	1659	154
4	4 Terminal Standard Resistor (all values)	1682	273
4	4 Terminal Standard Resistor (all values)	3111	445
4	4 Terminal Standard Resistor (0.001 Ω)	660	589
4	4 Terminal Standard Resistor (0.0005 Ω)	660	589
4	4 Terminal Standard Resistor (0.0001 Ω)	660	731
4	**Saturated Standard Cell** (Unmounted)	4305	58
4	Saturated Standard Cell (Mounted, Single Cell)	1268	78
4	Saturated Standard Cell (Mounted, Double Cell)	1149	128
5	**Constant Temperature Standard Cell Enclosure** (Mounts 4 Type 4305 Cells)	9152	697
5	Constant Temperature Standard Cell Enclosure (Mounts 12 Type 4305 Cells)	9152A	861
	NOTE 1: Price of Constant Temperature Enclosures does not include standard cells.		
5	**Volt Ratio Box**	9700	3814
5	Volt Ratio Box	9700A	4456
5	Volt Ratio Box	4281A	315
5	Volt Ratio Box	4281B	315
5	Volt Ratio Box	4281C	239
5	Volt Ratio Box	4281D	239
5	Volt Ratio Box	4281E	239
5	Volt Ratio Box	4281F	203
5	Volt Ratio Box	4281G	427
6	**Secondary Galvanometer** (For use with Photocell Amplifier Type 5214)	SR21	283
6	Photocell Galvanometer Amplifier (For use with Secondary Galvanometer Type SR21)	5214	704
	NOTE: A 6.3 V constant voltage transformer (not supplied), similar to the Sola Model 20-05-030 is required for operation with the Photocell Amplifier Type 5214.		
6	Thermal Compensating Unit (For use with Photocell Amplifier Type 5214)	5214A	109
6	Galvanometer	5180	241
7	Galvanometer	4500/SR4	277
7	**Low Thermal Chopper** (2 DPDT Switches)	9742	295
7	Low Thermal Chopper (3 DPDT Switches, miniaturized version)	9743	381
7	Low Thermal Chopper (4 DPDT Switches)	9744	500
8	**Low Thermal Selector Switch**	9145	343
8	Reversing Switch	9600	440
8	Dual Contact Switches (copper contacts only)	Listed on reverse side	

***PRICES INCLUDE CUSTOMS DUTY, BROKERAGE, PACKAGING, CONVERSION TO AMERICAN DOLLARS AND ALL OTHER SPECIAL HANDLING CHARGES.**

NOTE A: The type 3589S is erroneously listed in the catalog as being a 6 figure potentiometer. It is a 5 figure instrument.

SENSITIVE RESEARCH INSTRUMENT CORPORATION

310 MAIN STREET, NEW ROCHELLE, N. Y.

BEverly 5-2300

LOW THERMAL COPPER SWITCHES

	Poles	5/16" Stud Diam.			3/8" Stud Diam.			1/2" Stud Diam.		
		Base Price 2 Pos.	Add. Price Per Pos.	Max. Poss. Pos.	Base Price 2 Pos.	Add. Price Per Pos.	Max. Poss. Pos.	Base Price 2 Pos.	Add. Price Per Pos.	Max. Poss. Pos.
SINGLE BRUSH	1	$ 63	$ 1	25	$ 67	$ 1.50	25	$ 73	$ 2	16
	2	81	2.50	12	83	4	12	85	6	6
	3	95	10	7	98	14	6	104	8	3
	4	106	15	4	126	17	4	147	—	—
DOUBLE BRUSH	1				$ 77	$ 2	25	$ 80	$ 3	16
	2				95	5	12	97	9	6
	3				113	16	6	116	16	3
	4				146	21	4	168	—	—
TRIPLE BRUSH	1							$256	$ 7	11

Prices include customs duty, brokerage, packaging, conversion to American dollars and all other special handling charges.

EXEMPTION FROM BUY AMERICAN ACT

All "COMMANDER" instruments are of Canadian origin and come under Federal Class Code 6625. In accordance with ASPR 6-103 and 6-104, the Buy American Act restriction for military procurement is waived, and "COMMANDER" instruments are considered as United States equipment.

DUTY FREE ENTRY OF "COMMANDER" INSTRUMENTS

Duty free certificates can be obtained for "COMMANDER" instruments in accordance with ASPR 6-605 (Revised Oct. 1, 1959). Where the material requisitioned is for purposes of National Defense, duty free entry can be accorded Canadian supplies upon proper application of the cognizant contracting governmental agency.

Duty Free Certificates cannot be issued where the duty is less than $50.00.

DUTY FREE PRICES

Special quotations will be given in those cases where a duty free certificate is applicable.

WARRANTY

Potentiometers, Bridges, Volt Ratio Boxes and Standard Resistors are warranteed for five years, all other models for one year.

CERTIFICATION BY NBS OR NRC

"COMMANDER" instruments may be forwarded for certification to either the National Bureau of Standards in Washington, D. C., or Boulder, Colorado, or the National Research Council in Ottawa, Canada. In the case of NBS, it is preferable that purchase orders for such services be made out directly to that organization. Quotations can be issued by Sensitive Research to cover all testing accomplished by NRC.

ORDERING INFORMATION

Orders should be made out to Sensitive Research Instrument Corporation, 310 Main St., New Rochelle, N. Y.
Terms: Net 30 days. F.O.B.: Rouses Point, N. Y.

"COMMANDER" instruments are manufactured for Sensitive Research by Guildline Instruments, Ltd.—formerly Tinsley Instruments (Canada) Ltd.

'SENSITIVE RESEARCH' Field Engineers All Over The World!

Met. New York, No. New Jersey
SENSITIVE RESEARCH HOME OFFICE
New Rochelle, N. Y. Beverly 5-2300
Washington, Oregon, Idaho, W. Montana, Hawaii & Alaska
ARVA, INC.
Seattle, Wash. Main 2-0177
Portland, Ore. Capital 2-7337
Honolulu, Hawaii 506-096
No. & So. Carolina, So. Virginia
JAMES L. HIGHSMITH & CO.
Charlotte, No. Car. Franklin 7-2546
Richmond, Va. Elgin 9-1411
California, Arizona, Nevada
McCARTHY ASSOCIATES, INC.
Pasadena, Cal. Murray 1-7411
Menlo Park, Cal. Davenport 6-7937
San Diego, Cal. Broadway 4-1100
Ga., Kentucky, Tenn., Ala., Fla., Miss.
BIVINS & CALDWELL
Atlanta, Ga. Cedar 3-7522
Huntsville, Ala. 534-5733
Orlando, Fla. Cherry 1-1091
No. Illinois & So. Wisconsin
SAFFRO & ASSOCIATES
Chicago, Ill. Juniper 8-0905

Indiana
LAW INSTRUMENT COMPANY
Angola, Ind. 217 & 8101-R
Indianapolis, Ind. State 7-0009
Kansas, Missouri, So. Ill.
HARRIS-HANSON COMPANY
Kansas City, Mo. Hiland 4-9494
St. Louis, Mo. Mission 7-4350
Michigan, Ohio, W. Penna., W. Va.
S. STERLING COMPANY
Detroit, Mich. Broadway 3-2900
Cleveland, O. Hillcrest 2-8080
Dayton, O. 'AX 8-7573
Pittsburgh, Pa. Tuxedo 4-5515
Minnesota, Iowa, Nebraska, No. & So. Dakota, No. Wisconsin
THE HEIMANN COMPANY
Minneapolis, Minn. Federal 2-5457
New Mexico
GENE FRENCH COMPANY
Albuquerque, New Mexico Amherst 8-2478
Eastern Penna., So. New Jersey
I. E. ROBINSON COMPANY
W. Conshohocken, Penna. CH 8-1600 (Phila.)
Camp Hill, Penna. Regent 7-6791
Asbury Park, N. J. Kellog 1-3150

Central New York
J. F. WULFETANGE, JR.
De Witt, N. Y. Gibson 6-3330
Western New York
THE ROBERT F. LAMB COMPANY
Buffalo, N. Y. Tr 6-3757
New England & Eastern New York
YEWELL ASSOCIATES, INC.
Burlington, Mass. Browning 2-9000
Bridgeport, Conn. Forest 6-3456
Poughkeepsie, N. Y. Grover 1-3456
Texas, Oklahoma, Louisiana, Arkansas
ARNOLD BARNES COMPANY
Dallas, Texas Lakeside 6-8735
Tulsa, Okla. Temple 5-9252
Utah, Colo., Wyoming, East. Mont.
LAHANA & COMPANY
Denver, Colo. Pearl 3-3791
Salt Lake City, Utah Hunter 6-8166
Washington, D. C., Maryland, Dela.
HORMAN ASSOCIATES, INC.
Rockville, Md. Hazelwood 7-7560
Baltimore, Md. Mohawk 4-4400

SENSITIVE RESEARCH INSTRUMENT CORPORATION

310 MAIN STREET, NEW ROCHELLE, N. Y.
BEverly 5-2300

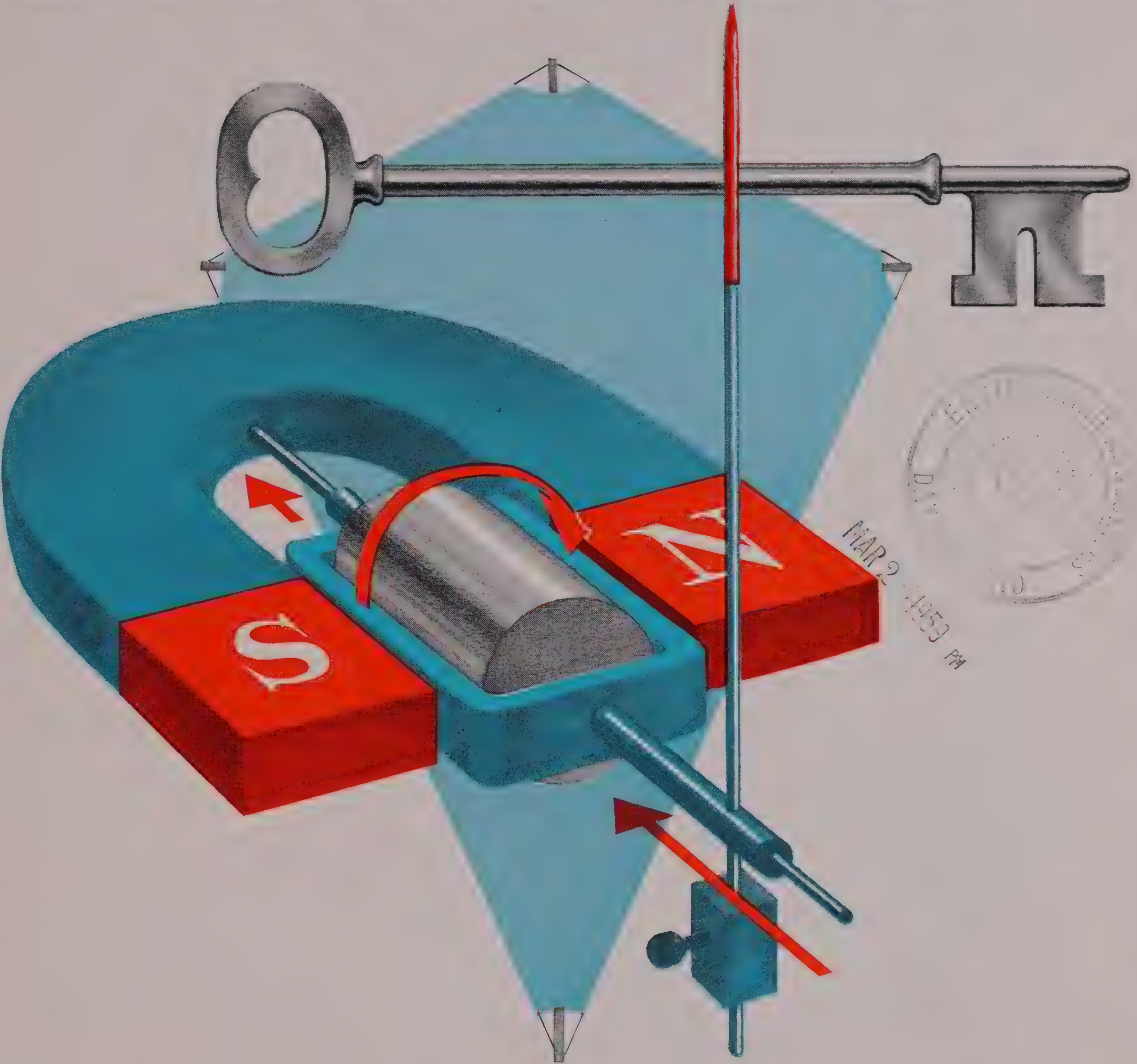
Printed in U. S. A.

Prices and specifications are subject to change without notice.

Sensitive

INSTRUMENTS AND AUTOMATION

INCLUDING: INSTRUMENT MANUFACTURING • JOURNAL OF THE SCMA • SIMULATION COUNCIL NEWSLETTER



MAR 2 1959 PM

in this issue:

JANUARY 1959

Accuracy Factors of Basic Movements
by H. Russell Brownell

Uses of Basic Electrical Instruments
by H. Russell Brownell, Vincent P. Cronin
and Marvin I. Steinberg

Reprinted By Courtesy Of
SENSITIVE RESEARCH INSTRUMENT CORP., NEW ROCHELLE, NEW YORK

Accuracy Factors of

Knowledge of the various movement constructions and principles is necessary for proper selection and use of basic electrical movements. Grades of accuracy and scale factors also are discussed.

NO AMMETER OR VOLTMETER automatically points to the right value for all given applications. You can rely on any properly designed instrument only if you know what it is supposed to read and how the instrument operates. For example, consider these two commonly "accepted" statements:

1. Ammeters measure current and are connected in series with the load. Therefore, it is proper to use an ammeter with the lowest possible resistance in order to minimize our loss and avoid introducing a load error.

2. Voltmeters measure potential difference and are connected in parallel with the load. Therefore, it is proper to use a voltmeter with the highest possible resistance in order to minimize our loss and avoid introducing load errors.

These two "common sense" statements are NOT always true. A study of the factors governing accuracy in the usual type of electrical indicating instruments shows the reasons why these commonly held beliefs are sometimes wrong.

Sensitivity vs Accuracy in a P-M M-C Movement

The permanent-magnet moving-coil type of instrument (Fig. 1) is commonly called a D'Arsonval movement, although this name should be reserved only for suspended galvanometers. This is the simplest ordinary type of d-c instrument; the magnet is usually of Alnico. A turning force, developed due to current through the moving coil, acts in opposition to a spring and thus moves a pointer across a scale by an amount proportional to (1) the current through the coil, (2) the number of turns in the coil, and (3) the flux density in the gap.

We can do three different things to increase the sensitivity of the instrument:

1. We can install *weaker springs,* but we reach a limit when the spring gets so weak that it tends to sag and fall out of shape.

2. We can increase the *strength of the magnet* and thus the flux density in the gap. Once again we reach a limit, the limit of commercially available magnet materials.

3. We can increase the number of *coil turns.* We can only increase the turns by using finer wire and we quickly reach a limit with the finest wire that is possible to obtain. Note that we are limited in all possible approaches to increasing the sensitivity.

Increasing the magnet strength or the number of turns will not directly affect the instrument's accuracy or ruggedness, but *changing the spring strength will.* The stronger the spring, the better the movement is held in position, and the more repeatable will be the reading. Inaccuracies due to friction and stickiness in the operation of the movement will tend to be swamped out as the spring strength is increased.

Designing for use with a stronger spring means that we must develop greater amounts of torque in order to swing the pointer to full scale. This means that we must put on more turns and thus increase the resistance of the moving coil. Therefore, we may say that if we want a high-accuracy rugged instrument, we must pay for it by having higher resistance. This statement is, of course, based on the current sensitivity of the d-c instrument.

If in current measurements you specify an extremely low-resistance instrument, remember that you *must pay for it* in more susceptibility to friction and lack of perfect centering of the coil; these factors tend to *reduce the over-all accuracy* and ruggedness of the instrument. In other words, you have a lower accuracy instrument any time you specify the instrument with the lowest resistance. For best instrument accuracy, the specification should always call for the highest resistance the circuit can possibly tolerate for all *current* measurements.

The converse of the above statement is true for voltmeters. The tendency is to specify a high resistance instrument to reduce the load on the circuit; unless

Basic Movements

H. RUSSELL BROWNELL
Sensitive Research Instrument Corp.

this is an absolute circuit necessity, *don't do it!* Specify a *low-resistance* voltmeter and allow it to burn up some power. In burning up that power, it will operate with stronger springs and be a better, higher accuracy instrument.

Another popular fallacy occurs when the design engineer says, "I am going to work in the range from 10-100 mils, so I'll buy a 4-range instrument with ranges of 1 mil, 10 mils, 100 mils and 1,000 mils." The *most sensitive* range of an instrument determines how good the instrument is—the more sensitive the basic range, the less accurate and more expensive the instrument will be. In general, therefore, the statement can be made—*do not add range extension in the direction requiring greater sensitivity unless these more sensitive ranges are necessary.*

Position vs Accuracy

When you require high sensitivity and high accuracy, one should always operate the instrument in a horizontal position (with the pivots in a vertical position). A vertical pivot working in a jewel bearing will drop into the middle of the circular jewel and give you a positive point about which the rotation takes place. If, however, you stand the instrument on edge and the pivots are in a horizontal position, they have a tendency to slide down a bit on one jewel and up on the other, and you have an uncertain center of rotation and reduced accuracy. *All instruments operate more accurately when the pivots are in a vertical position.*

Dynamometer Movements

The most common high-accuracy a-c instrument types use the dynamometer movement. The magnet of the permanent-magnet moving-coil type of instrument is replaced by a pair of field coils which provide the magnetic field in which the moving coil rotates (Fig. 2).

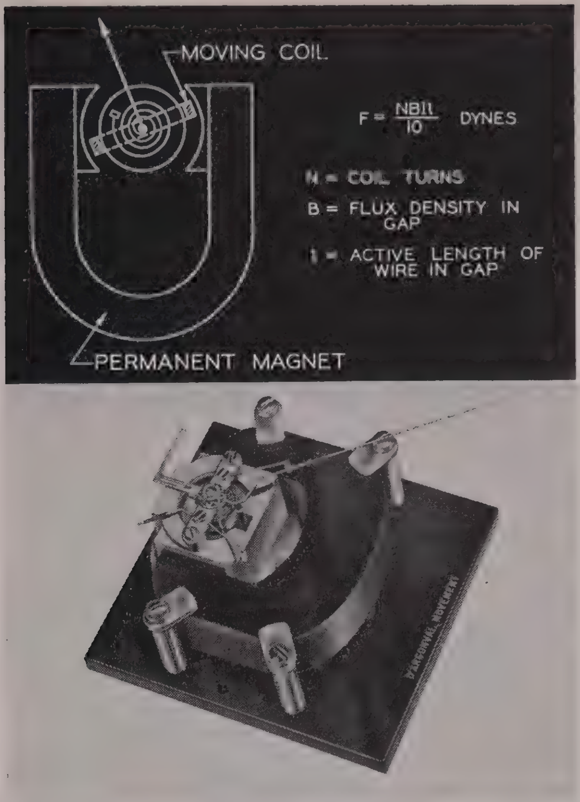
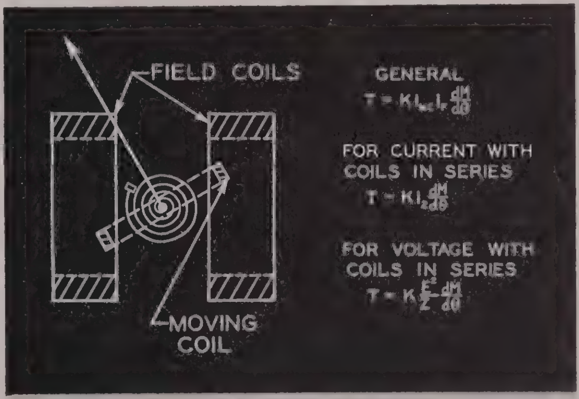

MOVING COIL
$F = \frac{NBIl}{10}$ DYNES
N = COIL TURNS
B = FLUX DENSITY IN GAP
l = ACTIVE LENGTH OF WIRE IN GAP
PERMANENT MAGNET

FIG. 1. PERMANENT-MAGNET moving-coil instrument. Top shows force-balance elements; bottom shows typical structure.

FIG. 2. DYNAMOMETER movement is best a-c movement and can be calibrated with dc.


FIELD COILS
GENERAL
$T = KI_{mc}I_{f}\frac{dM}{d\theta}$
FOR CURRENT WITH COILS IN SERIES
$T = KI^{2}\frac{dM}{d\theta}$
FOR VOLTAGE WITH COILS IN SERIES
$T = K\frac{E^{2}}{Z}\frac{dM}{d\theta}$
MOVING COIL

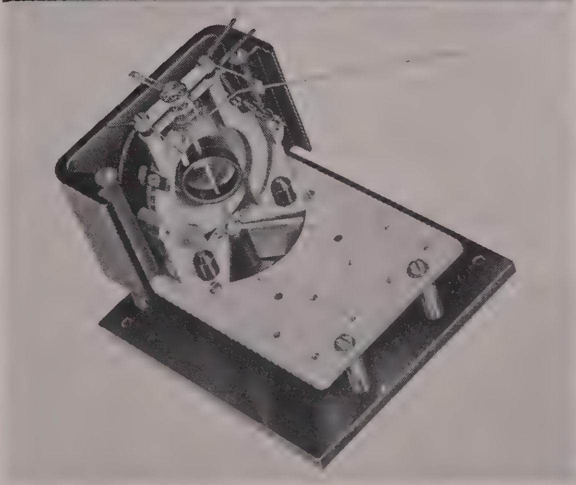


FIG. 3. DYNAMOMETER with one field coil removed to show moving coil and air damping vane.

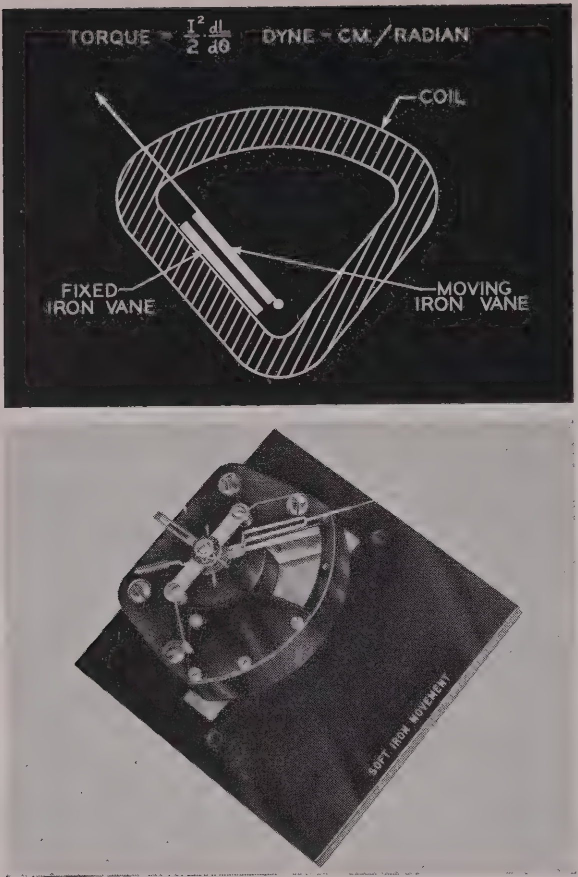


FIG. 4. MOVING-IRON instrument is limited in frequency. Top shows basic elements; typical structure is shown at bottom.

In this instrument the torque is equal to a constant times the current in the moving coil, times the current in the field coil. If we put the two coils in series (as one normally does for use as an ammeter or a voltmeter) the currents in the two coils are equal and the formula reduces to a constant times the current squared (KI^2). Thus the instantaneous torque is proportional to the square of the current through the two coils.

The scale itself contains a square-root factor and, therefore, the reading becomes directly proportional to the root mean square (RMS) value of the current through the two coils. This is important because ordinarily one is interested in the RMS values of the current or voltage involved. Some other types of instruments do not give true RMS values of torque but are calibrated in terms of RMS and hence are accurate only for sinusoidal voltages or currents, as will be seen.

When measuring voltage (by adding a series resistance) the dynamometer movement develops torque proportional to E^2 and, therefore, is again a true RMS indicating instrument for voltage.

The dynamometer is one of the most accurate types of a-c instruments although it does have a relatively heavy and inefficient movement. If we run the maximum current possible through the field coils (limited by a tolerable heating effect), the field produced is still weaker than that of a permanent magnet. This weaker magnetic field means that the torque is considerably lower than would be obtained for similar current in the permanent-magnet moving-coil instrument. Because of this factor, dynamometer instruments cannot be furnished in the high current sensitivities obtainable in the permanent-magnet moving-coil instrument.

The dynamometer instrument, although relatively inefficient and requiring appreciable amounts of power to operate, has an important place in lower frequency a-c measurements which cannot be fulfilled by any other type of instrument because of (1) its inherent true RMS response and (2) its ability to operate for both dc and ac.

Fig. 3 shows a dynamometer movement with one field coil removed so that the moving coil can be seen in position. Below the base plate can be seen the aluminum air damping vane which, moving back and forth in a close fitting chamber, provides the necessary movement damping.

Moving-Iron Movement

A common type of a-c instrument is the moving-iron instrument (Fig. 4). This instrument has two iron vanes—one fixed and one pivoted—both surrounded by the current carrying coil. When current flows in the coil, both vanes become magnetized with identical polarities and thus tend to repel each other. This magnetic repulsion provides a torque which moves the pointer over the scale. The flux in each vane is proportional to the current, and the repulsion force is porportional to the product of the fluxes. Therefore, we again end up with a square factor in our torque formula and have a true RMS-indicating instrument.

The moving-iron instrument tends to be less expensive to construct than the dynamometer. It is somewhat less accurate at higher frequencies because of the magnetic material within the coil and the attendant problems of raised inductance, nonlinearity effects, and similar factors.

Electrostatic Movements

The electrostatic instrument (Fig. 5) is the only instrument made which is truly a "voltmeter." All other types of voltmeters are actually current meters with added series resistance which makes the current become proportional to voltage, and their deflection actually results from the current flow. In the electrostatic movement, the deflection is caused not by current but by the actual voltage applied to the two vanes. As the formula for torque involves E^2, the indications are true RMS values of voltage.

On dc the only current drawn is that of the leakage across the insulation. Thus the leakage d-c resistance is in the order of 1×10^{13} ohms; this results in negligible leakage current for most d-c applications. However, when used on high-frequency ac, the capacitance of the instrument can result in appreciable current being drawn from the circuit, but this current does not contribute to the torque.

A-C Measurement with D-C Movements

Many a-c voltmeters are merely ordinary d-c instruments in series with a resistance and a rectifier. This may be a tube rectifier, a copper-oxide rectifier, silicon or germanium diodes, or any other type. As shown in Fig. 6, such a voltmeter has a torque proportional to the *average value* of the impressed voltage E. There is no E^2 term, and this instrument will *not* give true RMS value except in special cases.

What is normally done in such an instrument is this: As the average value of E in a rectified sine wave is 0.636 of the peak value, and as the RMS value is 0.707 of peak, the scale is graduated in terms of 1.11 times the average value. If you have a sine wave input, the pointer will point to the RMS values because of the inclusion of this 1.11 factor in the scale. If, however, you use the instrument on anything except a sine wave, the pointer will point to 1.11 times the average value of this wave, which will *not* be the RMS value of this nonsinusoidal wave.

Full-Wave Rectifier

In the full-wave rectifier (Fig. 7) the torque formula is practically the same except for a factor of 2. This method of providing an a-c instrument with a d-c movement is very common and high impedance instruments can be provided with this type of circuit. It is sensitive and accurate on any wave form—if one remembers that its reading is in terms of 1.11 times the average and not in terms of RMS values.

Thermal Convertor

Fig. 8 shows a much abused and sadly misunderstood instrument, and one of the common ways of making an a-c instrument from a d-c movement (a millivoltmeter). We apply the current to the thermocouple through resistance R_2 (we are assuming now that we are going to measure voltage) and R_1 is the heater wire. There is a thermocouple junction attached to R_1 whose voltage output will be proportional to some constant times the temperature of R_1. The temperature of R_1 will be proportional to the wattage dissipated in R_1 which, of course, is I^2R_1; thus we have an I^2 term, and the instrument once again is a true RMS instrument.

Thermocouples have many advantages: (1) They are extremely high frequency devices. Voltmeters and current meters can be made to operate up to several megacycles. In fact, the thermocouple provides the highest frequency measurement which can be made with direct indicating instruments. (2) They have relatively high sensitivities. Voltmeters can be made with a sensitivity of 500 ohms per volt. (3) They have true RMS response. These are the advantages, but: YOU HAVE TO BE CAREFUL IN USING THEM. You can burn out the thermojunction without knowing it, as follows:

The I^2 factor, which causes the true RMS response, causes the operating temperature of the heater to go up as the square of the current through it. Triple the current and the temperature goes up nine times.

Fig. 9 shows what can happen. As the thermocouples of these instruments are made of fine wire, they can reach burnout temperature in a fraction of a second when the current is high. The instrument's pointer, however, cannot move that fast (the instrument is ordi-

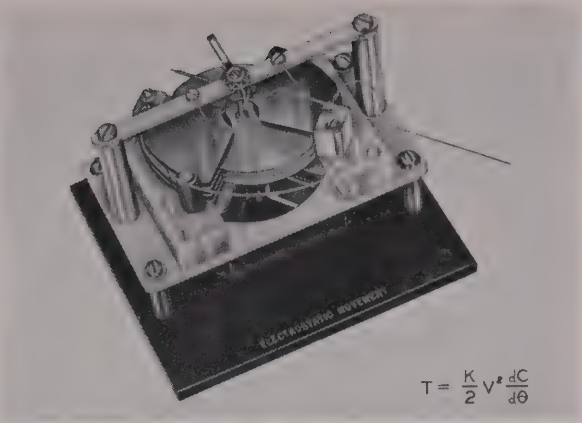


FIG. 5. ELECTROSTATIC VOLTMETER is only true "voltmeter" and has very high d-c resistance.

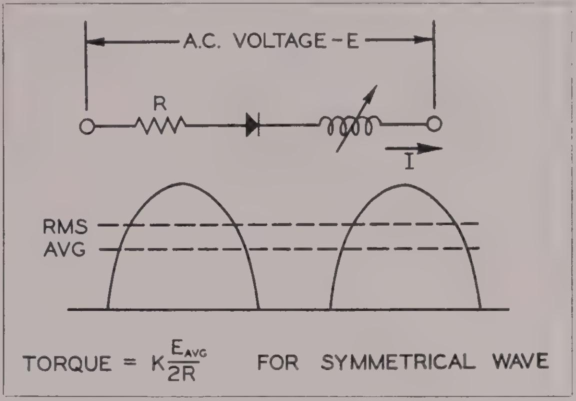


FIG. 6. A-C VOLTMETER using half-wave rectifier and d-c movement. Waveform shows relationship of average to RMS values.

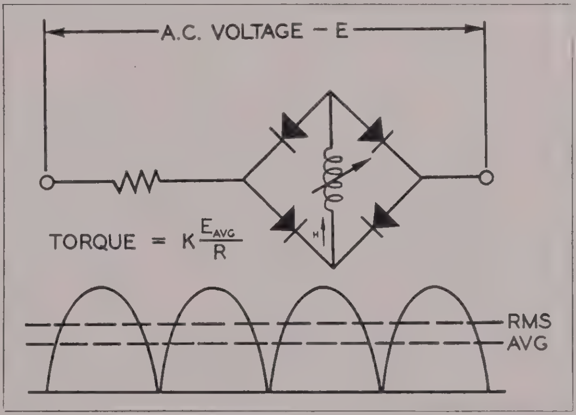


FIG. 7. A-C VOLTMETER using full-wave rectifier plus d-c movement.

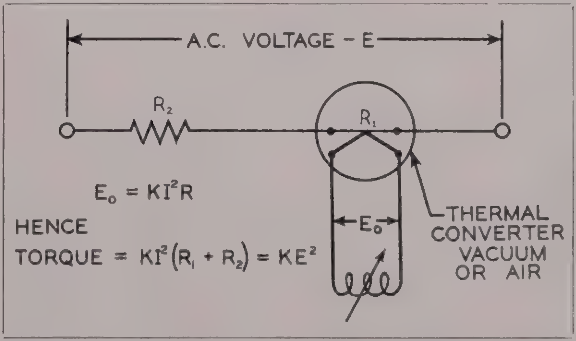

A.C. VOLTAGE – E
R_2
R_1
$E_o = KI^2R$
HENCE
$TORQUE = KI^2(R_1 + R_2) = KE^2$
E_o
THERMAL CONVERTER VACUUM OR AIR

FIG. 8. AC is measured by thermocouple on heater wire. Thermocouple output is shown by d-c millivoltmeter.

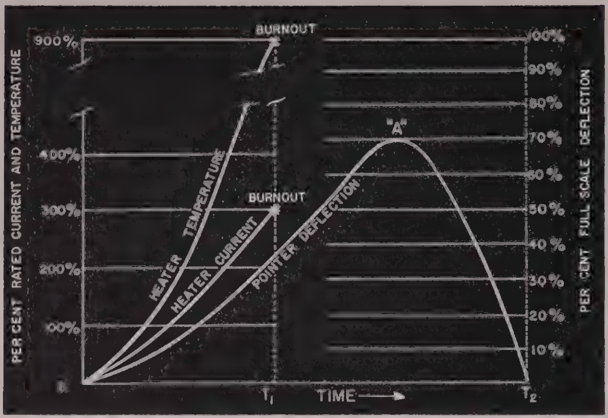


FIG. 9. CURRENT OVERLOAD can burn out thermocouple before pointer approaches full-scale reading.

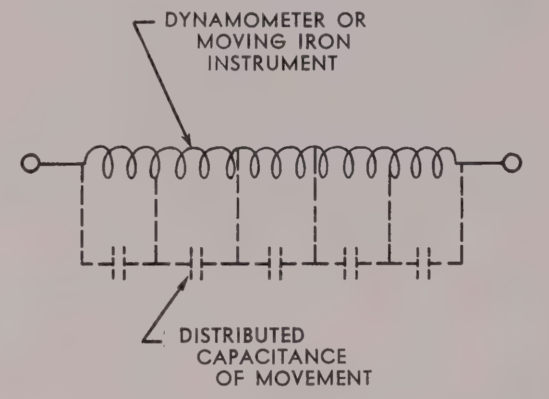


FIG. 10. ANY INDUCTANCE (coil) has distributed capacitance between turns.

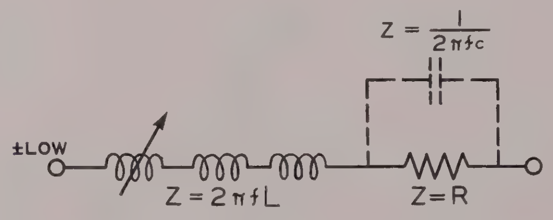


FIG. 11. COMPENSATION of dynamometer movement with capacitor (dotted line) will increase current with frequency to compensate for loss of current through distributed capacitance.

narily heavily damped). As shown in Fig. 9, the current is 300% overload at time T_1 and the thermocouple has actually reached the burnout point, but the sluggish pointer has reached only 40% of scale. As it is moving upward it will coast to a higher point even though the heater is now no longer supplying any temperature to provide thermocouple output. However, before it actually reaches full scale, it will begin to drop back. This factor of the thermocouple burning out much faster than the pointer can respond is the reason for the plaintive comment so often heard: "I didn't burn it out—the pointer didn't go off scale." However, examination of Fig. 9 shows that the thermocouple was overloaded even though the pointer did not go off scale.

Inductive surges are another source of danger. Consider a transformer with dc in the primary, and a thermocouple-type voltmeter across the secondary. If we interrupt the dc in the primary, we get a rapid flux change that can produce a terrific output voltage, limited only by the saturation value of the transformer core. Such a sharp peak can readily burn out the thermocouple.

If we do the same thing with ac in the primary, the switch which breaks the circuit ordinarily will arc slightly and the current will carry over and approach zero gradually, but if we throw the switch often enough, there will come a time when the current will actually break at a peak rather than at zero, and we will get the same terrific transient in the secondary. Once gain the thermocouple, which would take the normal voltage, burned out with the transient peak. The better the quality of the transformer, the more easily it can wreck the thermocouple. The safe way to break the primary circuit is to use a variable transformer in the primary and reduce the current to zero gradually.

Inductive surges are not the only possible cause of trouble. The same thing can happen from a capacitance in the circuit. Any place where there is a possibility of stored energy which can suddenly be discharged into the circuit may be a cause of serious grief to any thermocouples that receive such transient effects. All circuits using thermocouple instruments should be carefully considered with these factors in mind.

Frequency Effects

Dynamometer and moving-iron a-c instruments have relatively high inductance values. Their coils have distributed capacitance (Fig. 10). At higher frequencies an increasing percentage of the current goes through the distributed capacitance and thus does not traverse all the turns of the instrument. Therefore, most dynamometer or moving-iron current instruments tend to read low as the frequency is increased. There are some things you can do about it, within limits.

In a dynamometer voltmeter, the moving coils and the two field coils are connected in series. Also in series is a resistor R (Fig. 11). As the frequency goes up, the inductive impedance goes up, but the impedance of R remains constant. Thus the total impedance which determines the current through the movement will vary with frequency, depending on the ratio of R to L. It is obvious that the frequency characteristics of the instrument will be better if the R to L ratio is high. We can do a certain amount of correction by introducing a capacitance across R so that impedance will tend to go down with frequency. Unfortunately, neither of these effects is linear and you can obtain only approximate compensation this way. Such compensation can be done for instruments operating to as much as 2500 cycles, but seldom higher. When used to the maximum extent, this type of compensation will give an inductive error at low frequency and the instrument will read "low" by the amount of its guaranteed frequency error. At some intermediate point, the capacitive and inductive elements will exactly cancel, and the frequency error will be zero. At the upper limit of frequency, the error will tend to be capacitive and the

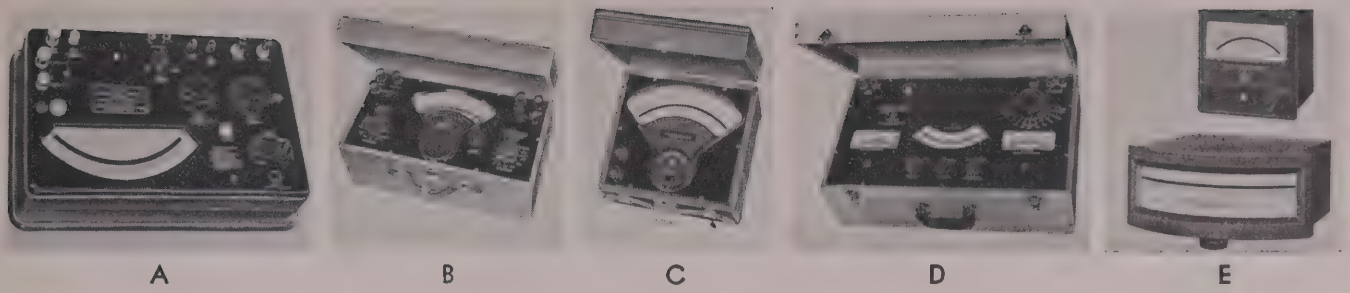


FIG. 12. A SHOWS a d-c laboratory standard instrument (volt-amp-milliammeter) with accuracy of 0.05%, realized by use of a built-in standard cell for checking the instrument accuracy. B shows a portable ac-dc volt-milliammeter with accuracy of 0.5% dc and 0.75% ac. C shows a direct-reading frequency instrument with accuracy of 0.25%. D shows a magnetic-core-loss testing set with self-contained ac ammeter, voltmeter, and low-power-factor wattmeter. E shows different types of multirange panel-mount instruments. (Courtesy Sensitive Research Instrument Corp.)

top frequency will read "high" by the full amount of the guaranteed frequency tolerance. Here, you take up the entire guarantee in tolerance in both dirctions.

Grades of Accuracy

Several general grades of accuracy are involved in electrical instruments. The highest are those with error tolerances of less than 0.01%. These are commonly called "Bureau of Standards type" measurements, although there are several laboratories whose measurements can be considered to be in this class for many ranges of electrical values. These measurements require engineering supervision, and can usually be undertaken only by skilled personnel.

Next in order of accuracy are those measurements made in many laboratories with potentiometers, 4-terminal standard resistors, standard cells, and similar high accuracy devices. These are often referred to as *potentiometric type* measurements. Accuracy is in the range of approximately 0.01% to about 0.05%. These are routine measurements and can be made with reasonable speed. They can be carried on by semi-skilled technical help of less than engineering level with a reasonable amount of training.

Immediately below this level of accuracy comes the best of the direct indicating instruments, usually referred to as *laboratory standard instruments.* These are ammeters, voltmeters, wattmeters, etc., with accuracies of 0.05 to 0.15%. They are long-scale laboratory-type instruments requiring clean, vibration-free, temperature-limited areas, and protection against overload abuse and similar mistreatment to insure long term stability. Readings with this type of instrument are rapid. In recent years a number of routine commercial measurements have required this degree of accuracy, and instruments of this type are now often seen in actual production equipment.

The next class of instruments has no generally accepted name. They are variously known as *portable standards, secondary standards,* or sometimes transfer standards* because of their common use for transfer of measurements from the laboratory to production equipment.

Accuracies in the order of 0.25% and 0.5% are common in this class; some in the extremely high sensitivity ranges are rated at 1%. When used for the calibration of production equipment, such instruments must have an appreciably higher accuracy than the equipment being calibrated, and should be removed from the actual production instruments for several reasons: (1) The intermediate instruments take a lot of use off the plant standard instrument thus increasing long term stability. (2) It allows the plant standards to remain in the laboratory and prevents "in transit" damage during production checks. (3) It is usually possible to use multirange instruments as the intermediaries between the plant standards and the production equipment by making the laboratory checks at the same scale points that will be used for the production equipment checks.

Reference Accuracy Increments

The general thinking in regard to how much increased accuracy is required in an instrument to use for checking another instrument has changed in recent years. The factor of 10, which many organizations have for many years felt necessary, has been modified. Factors of 2 to 4 are now generally accepted as satisfactory. This means that to check 1% production instruments, 0.25% or even 0.50% instruments are satisfactory in normal operation. In practice, there may be good reason for checking against instruments of the same accuracy class. For example, instruments sometimes are subject to overload in normal operation. One instrument of the same grade, kept aside and used as a reference for those in actual operation, will detect this type of difficulty.

The Meaning of Accuracy

Many people fail to apply correctly the fact that instrument accuracies are normally stated in terms of *percent of full-scale* value. For example, suppose we wish to measure a voltage of 30 volts. We have available a 50-volt ½% instrument and a 150-volt ¼% instrument. If we use the ½% instrument, we have an uncertainty of ½% of 50, or 0.25 volt. If we use the ¼% instrument, we have a measurement uncertainty of ¼% of 150, or 0.38 volt. Hence the more accurate measurement is made with the less accurate 50-volt instrument.

---

*The term "transfer standard" should be reserved for those instruments which are operable at full accuracy on both dc and ac, and are used for the transfer of potentiometric d-c measurements to a-c values.

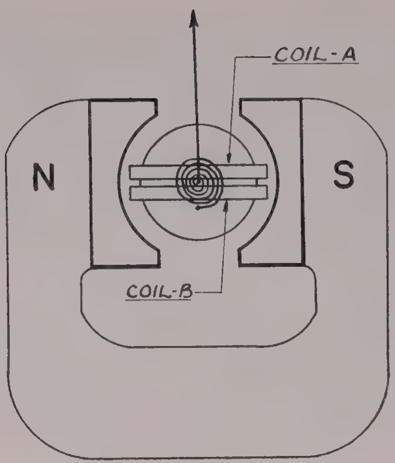


FIG. 1. PERMANENT-MAGNET moving-coil instrument with two coils will add or subtract. Use as comparator results in high accuracy.

LESSER KNOWN USES OF BASIC

It is not widely known that basic electrical movements can perform many computing functions, often with startling accuracies in comparative measurements.

BASIC ELECTRICAL INDICATING INSTRUMENTS can be used for addition, subtraction, comparisons, multiplying, intergrating, and other computing functions, with no electronic circuitry. In many cases startling comparative accuracies can be obtained.

Differential Movement

If we take an ordinary permanent-magnet moving-coil instrument and, instead of winding a single coil, wind two coils (Fig. 1), we produce what is commonly called a *differential instrument.* If we put a current through coil A, the instrument deflection is proportional to that current. If we put a current through coil B, the instrument deflection is proportional to this current. If both coils are identical and if we put currents through both coils in the same direction, we have an instrument that indicates A plus B. It will *add* any two current values and the pointer indication will be proportional to the sum of the two currents.

This same instrument can be used for subtraction simply by reversing the current through one coil.

Let us assume that we make a 50-0-50 microammeter of this differential type. A current of 1 microamp in A and 0 current in B now gives you 1-division deflection due to the current in A. If, however, we put 100 microamps in A and 99 microamps in coil B, the pointer still indicates only 1 microamp (current A minus current B).

The advantage of this differential instrument comes from the fact that the above described 50-0-50 microammeter can handle momentary currents in the order of 10 milliamperes without damage to the instrument. Therefore, if we apply 10 ma to coil A and 10.001 ma to coil B, we obtain a 1-division deflection in the direction of the coil B. Note the accuracy. If we assume that our original 50-0-50 microamp instrument had an accuracy of ± 1% (± 1 division), it has ± 1 microamp accuracy with 10 ma flowing. In terms of the accuracy of comparison, we are now able to *compare* the 10 ma to an accuracy of 0.01% (1 division deflection). We do not know that one is 10 ma and the other 10.001, but we do know that their difference is .001 ma, and that the two currents are within 0.01% of each other.

This high comparative accuracy results from the overload characteristics of the permanent-magnet moving-coil instrument. Most of these instruments can be overloaded 100 to 1 temporarily, in some cases even 200 to 1. The basic accuracy of the instrument is effectively multiplied by the overload factor.

Current Comparator

In Fig. 2 we have a differential instrument in a circuit with a standard resistor, a high sensitivity galvanometer, and a standard cell. By means of the standard cell and galvanometer, we can know the current in one coil of our instrument to an accuracy in the order of 0.01%. With sufficiently stable power supplies, checking of this current once an hour can hold this degree of accuracy.

Now, by means of the differential instrument, we can compare other currents to this standardized value to a high degree of accuracy because of the overload characteristics of the differential instrument. We have turned our high comparison-accuracy into a high *absolute accuracy* by the addition of this standard cell circuit. Recent advances in high-accuracy high-stability power supplies are leading to the use of a type of circuitry using the high comparative accuracy of the differential and the high reference accuracy of special supplies to provide long-scale, high-readability, high-accuracy standard instruments.

Crossed-Coil Ratio Comparator

Fig. 3 shows a different type of comparison instrument. Instead of the usual angular gap, we have provided a magnetic structure giving a straight-line flux pattern. In this instrument coil 1, when it is supplied with current, tends to swing the pointer to the right as it moves to enclose a greater number of flux lines. Similarly coil B tends to swing the pointer to the left.

ELECTRICAL INSTRUMENTS

H. RUSSELL BROWNELL
VINCENT P. CRONIN
MARVIN I. STEINBERG
Sensitive Research Instrument Corp.

In this instrument currents are brought into the coils A and B by light, gold ligaments which introduce negligible restoring torque. There are no springs for restoring torque.

As the coils swing, they change the number of flux lines they enclose and thus change the torque which they provide. When currents are put through both coils simultaneously, the pointer takes up a position so that the coils produce equal and opposite torques. The one carrying the most current will, of course, be in a position to intercept the greatest number of flux lines. If all the current is in coil 1, the pointer swings to the right index. If all the current is in coil B, the pointer swings to the left index. If the two currents are exactly equal, the pointer remains vertical. For any currents, the pointer takes up a position which can be marked on the scale in terms of the ratio A/B. We now have a comparison device which gives literally infinite range, having zero at the left index and infinity at the right index, and covering the entire range between.

A specific use for this type of instrument is measurement of resistance while current is flowing (Fig. 4). Coil B is connected in series with resistance (R) to be measured. Coil A is connected to a series resistor to make its current proportional to voltage. If we now cause a current to flow through resistor R, the ratiometer pointer will assume a position which will indicate the ratio A/B, which in this case is the ratio E/I, E being the voltage across the resistor, and I being the current through it. This ratio (E/I) is R. Therefore, we can calibrate the scale of the ratiometer in terms of the resistance R, and it correctly indicates the value of R *regardless of the current or voltages applied.*

Let us describe one use for this technique which has proved of value in surgery. There is a tropical venereal disease in which the aorta tends to lose its strength and begins to swell out like a blow-out in a tire. Eventually it bursts and the victim dies.

Presbyterian Hospital in New York has developed a surgical technique where they feed a nickle wire inside of the aorta, like the reinforcing wire in a vacuum

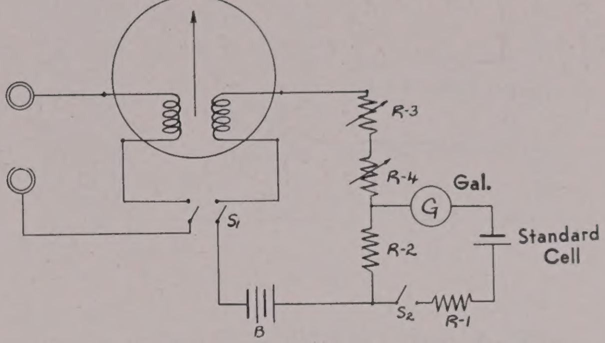


FIG. 2. CURRENT COMPARATOR compares unknown current in left coil with "standardized" current in right coil.

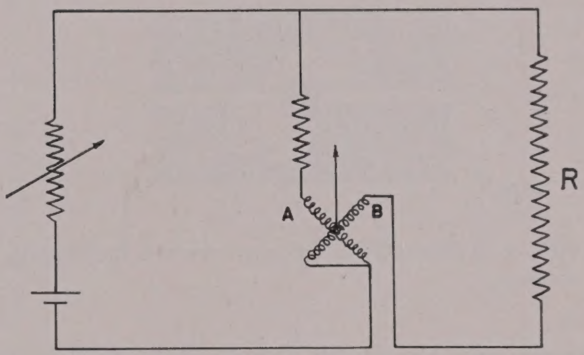


FIG. 3. MOVEMENT FOR obtaining the ratio of two currents.

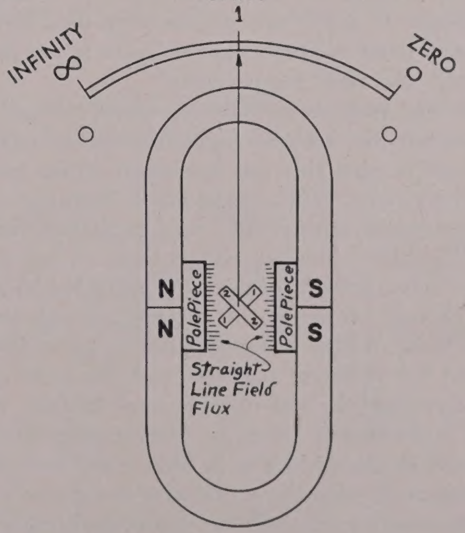


FIG. 4. THIS RATIO instrument can give resistance directly.

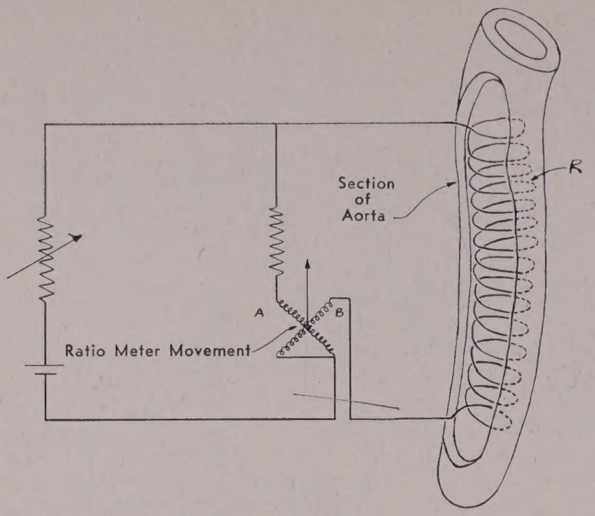


FIG. 5. RATIO TECHNIQUE used in surgery.

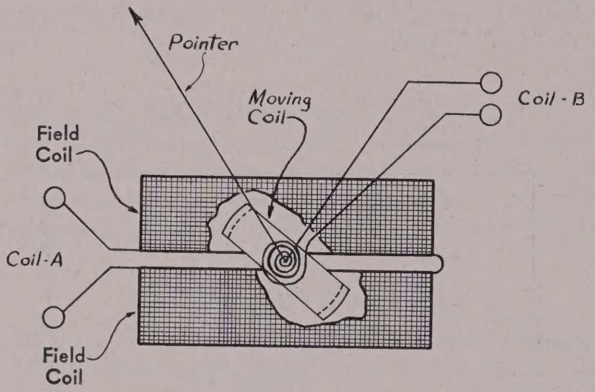


FIG. 6. DYNAMOMETER movement is multiplying element.

cleaner hose (Fig. 5). They run a current through this wire. If the wire reaches exactly the right temperature, it will sear the aorta walls and adhere to it, remaining to provide reinforcing for the aorta. It was so difficult to control the current properly that the operation was successful in about one out of four times. If the wire got too hot, it burned a hole in the aorta and the patient died then instead of a few weeks later. If it didn't get hot enough, it didn't sear to the aorta and the aorta eventually burst anyway. The trick was to get the wire to exactly the right temperature.

First they tried to measure the resistance by bridge methods because, with the high temperature coefficient of the nickle wire, this was a measure of the temperature of the wire. This necessitated throwing off the heating current during the actual period of measurement. The blood flow cooled the wires so fast that resistance measurements of this type proved to be of little value. Actual measurements of the current involved proved to be of little value because the blood flow was different for different patients, and the same current did not provide the same temperature in every case.

The problem was solved by setting up a ratiometer in the circuit shown in Fig. 5. This is the same as Fig. 4, resistance R being the actual wire in the man's aorta. The ratiometer now reads the actual resistance of the wire regardless of the current flowing at the moment. The operation was then performed several times and the ratiometer readings were recorded until a pattern of correct values could be obtained. As soon as this was determined, a red line was drawn on the scale, and it is now merely necessary to turn on the current, bring it up until the ratiometer indicates the correct resistance (which is also the correct temperature), hold it for an exact number of seconds, and turn it off. The ratio of successful operations has gone up from approximately one out of four to approximately eight out of ten.

Multiplying Dynamometers

The deflection of a dynamometer (Fig. 6) is proportional to the product of the current in the two coils. Thus if these are two separate currents, we have an instrument which automatically multiplies, and which operates on dc or ac.

If this instrument is used on ac, the phase angle between the two currents must be applied because the deflection is proportional to the current in coil A times the current in coil B, times $\cos\Theta$. This same formula ($AB \cos\Theta$) also defines torque in many mechanisms and a-c devices. For instance, in conventional servomotors, the torque is proportional to the current through one phase times the current in the other phase times the cosine of the angle between the two phases. If in making measurements on such a device we put one coil in phase A and the other coil in phase B, we can use a single meter to read torque instead of having to take two separate readings and the measure of phase angles.

Fluxmeter

The fluxmeter (Fig. 7) is the same basic permanent-magnet moving-coil instrument except that it is built without springs. The current is brought in and out of the moving coil by fine, gold ligaments that introduce negligible torque, and the pointer will stay at any position on the scale.

The simplest way to think of the action of this instrument is on the basis of conservation of energy. The moving coil is connected to an external search coil. As we have no way of getting energy into this circuit, the total flux linkages of the moving coil and the external search coil must remain constant. If we assume that the search coil is originally in a field of high flux density and the pointer is at zero, when the search coil is moved to a point of zero flux the moving coil must move so as to increase its own flux linkages to maintain the total constant. This movement, therefore, is a measure of external *changes in flux*.

The instrument measures the difference between the flux linkages where it was and the position to which it was taken. If you want to actually measure flux lines, you must either start or end at a point of zero flux.

If we substitute a resistor in place of the search coil (Fig. 8) and run a current through this resistor, the fluxmeter pointer tends to move continuously until it hits the pin at the end of the scale. The actual current flow is now indicated by the *rate* at which the pointer moves, and the actual distance traveled becomes proportional to the *integral* of that current with time. We have now made an integrating device that reads, not in terms of milliamperes, but in terms of milliampere-seconds.

There are two limitations which must be applied for accurate integration with the fluxmeter. The integration time cannot be longer than 15 or 20 seconds because the ligaments used do actually provide a slight torque and the instrument tends to drift. If the period of integration is long, this drift becomes appreciable. Also, the time cannot be so short that the signal is by-passed through the distributed capacitance of the moving coil. Hence integration is satisfactory for any phenomena which is complete in more than 10 or 15 microseconds and not longer than 10 or 15 seconds.

One widespread use of this type of measurement is in photographic work involving various types of shutters. A single reading of the fluxmeter, when supplied from a photocell circuit, provides a measure of total light flux passed regardless of the rate of opening or closing.

Frequency Meters

Frequency meters are included in this listing of computing instruments because in effect they count. One versatile type of frequency meter is shown in Fig. 9. Transformer TR is made with a square-loop-type of material. Resistor R is selected to provide sufficient current at operating voltage to drive the core material completely into saturation each half cycle. As the core goes completely into saturation, a constant volt-second integral output is achieved for each half cycle. If this is then rectified and sent through a d-c instrument which will integrate the pulses because of its long-term averaging characteristics, the meter deflection will be directly proportional to the number of times the core has been driven into saturation and thus can be calibrated directly in terms of the driving frequency.

When it is not desired to read from zero to a specific full-scale value, suppression can be accomplished and the scale read for a limited frequency range. This is commonly done by using two separate rectifiers and utilizing opposite halves of the wave. One half, fed into the metering circuit is proportional to frequency. The other half-cycle, picked off by a reverse rectifier, is fed into a voltage regulating circuit and a voltage is derived which is stable and *not* proportional to frequency. This voltage is used for a bias to provide offset operation. By this means, it is possible to obtain a 375-425 cycle instrument for the measurement of a 400-cycle apparatus. This basic type of frequency meter is a relatively sensitive device and performs satisfactorily up to several thousand cycles. The current drain can be as little as 5 ma on 115-volt circuits, compared with 40 or 50 ma with some other types of frequency meters. Normal accuracy is in the order of 0.25% of full scale.

In Fig. 10 is shown another common type of frequency meter in which coils A and B are fed from frequency-sensitive networks containing R and L. As frequency is increased, the current through A tends to decrease while the current through B tends to increase. The soft iron needle mounted within the coils tends to take up a position which is the resultant of the two currents and hence gives a pointer indication proportional to frequency.

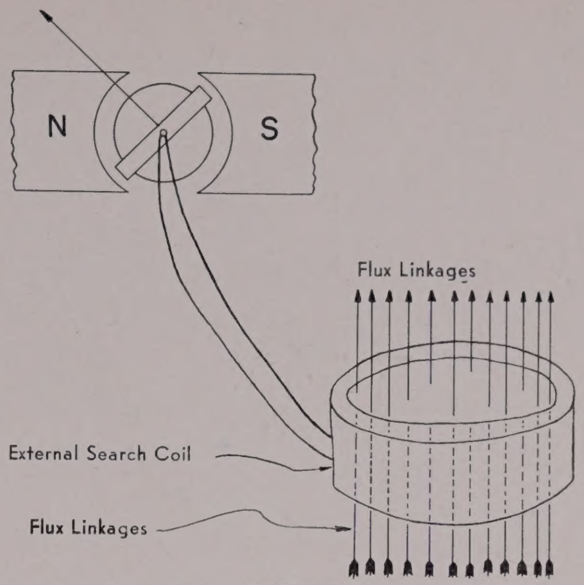


FIG. 7. P-M M-C MOVEMENT without spring is fluxmeter.

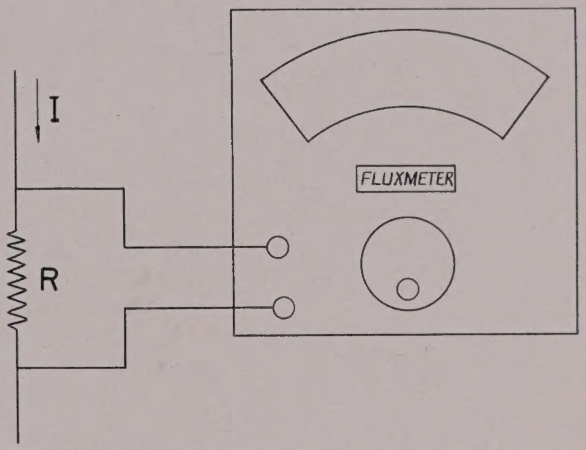


FIG. 8. FLUXMETER WITH resistor acts as integrator.

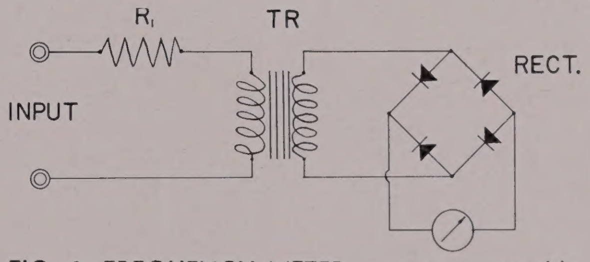


FIG. 9. FREQUENCY METER comprises saturable reactor, bridge-rectifier, and d-c instrument.

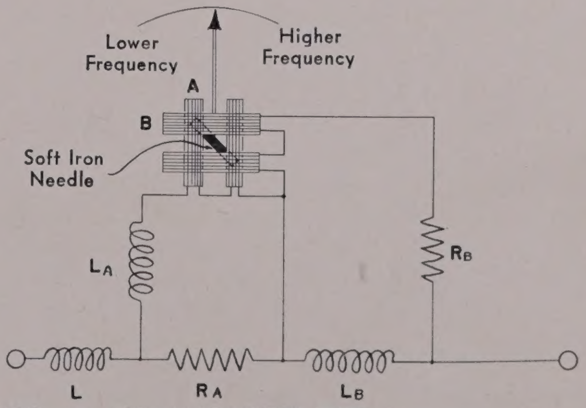


FIG. 10. DYNAMOMETER-TYPE frequency meter.

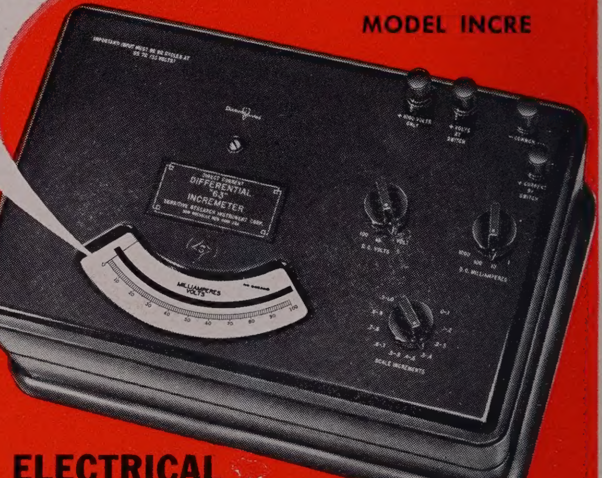
THIS MAY SEEM LIKE A LOT OF SCALES FOR *ONE* INSTRUMENT . . .

INCREMETER
0
10
20
30
40
50
60
70
80
90
100
SENSITIVE RESEARCH INSTRUMENT CORPORATION

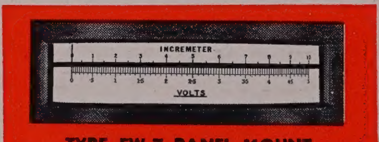
But—

THAT'S WHAT YOU GET in the *RADICALLY NEW* SENSITIVE RESEARCH INCREMETER*

MODEL INCRE


DIRECT CURRENT
DIFFERENTIAL
"63"
INCREMETER
SENSITIVE RESEARCH INSTRUMENT CORP.
MILLIAMPERES
VOLTS
D.C. VOLTS
D.C. MILLIAMPERES
SCALE INCREMENTS

*** By definition—A DIRECT READING DC ELECTRICAL INDICATING INSTRUMENT with an *EFFECTIVE SCALE LENGTH OF 63 INCHES* and an ACCURACY OF .05%.**


INCREMETER
VOLTS

TYPE EW-7 PANEL MOUNT

The Model INCRE essentially consists of a differential instrument of "high comparison accuracy" and a stable "high accuracy" reference source. The instrument's actual scale length is 6.3″, but this represents only 10% of its total effective scale length. Each 10% of its full scale range is selected by an incremental switch in effect creating a 90% scale suppression at all times. ***Ranges*** — single or multirange from 200 mv. full scale (lowest reading .2 mv.) and 200 microamperes full scale (lowest reading .2 microamperes). ***Resolution*** — effectively 1,000 scale divisions over a 63″ scale length. Each scale division has a value of .1%. ***Availability*** — portable or as a rack-mounted edgewise panel instrument. **The SRIC Differential "63" Incremeter** is a high resolution, *phenomenally* accurate measuring device with proven stability because it *is* an Electrical Indicating Instrument. **Diamond Pivoted of course!**

Write for additional information on the *NEW* "INCREMETER".

Symbol of Quality

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927